Energy Management Handbook
1996

State of Tennessee

Department of General Services

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State Building Energy Management Program

Second edition 1996
revised & prepared by

CRSI, Inc.
The Center for Research Service & Inquiry, Inc.

ENERGY MANAGEMENT HANDBOOK

Second Edition

1996

TENNESSEE DEPARTMENT OF GENERAL SERVICES
State Building Energy Management Program

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Contract # : FA-6-11676-6-00

PREFACE TO SECOND EDITION

This manual was first published in 1980. The first edition focused primarily on operations and maintenance, and low cost energy savings approaches. Most of the first edition has been retained, with some editorial changes. The format of the manual has been changed somewhat to make it easier to use. Most notably, the survey forms have been added, and attached to the end of the document in order that they may be removed and copied together. This should make the job of collecting data simpler. The lighting section has been expanded and re-titled to cover the complete electrical system. A section has been added to cover Energy Monitoring and Control Systems as well as a description of Building Commissioning.

In the fifteen years since the first edition was written, there have been significant changes in the field of energy and water conservation. Most of the low cost measures have been, or should have been, identified and implemented. The building energy audit should still include the low cost measures, because their effectiveness tends to decline over time. For instance, windows may need re-caulking. This edition has been expanded to cover the technological advances that have been made since the first edition. Because most of these advances involve significant cost and fall into the category of capital improvements, the coverage of capital improvements has been expanded. Written primarily for the building manager, coverage of the technical part of the capital energy conservation opportunities (ECOs) is intentionally brief, and concentrates on the practical aspects of energy savings. It is also recognized that economic analysis is essential to making a reasonable decision on capital investments. The reader is referred to the references in Chapter 9 for some excellent books on engineering economics as well as for additional technical coverage of the capital ECOs/retrofit projects.

This Energy Management Manual is expressly prepared as a guide for planning and implementing building energy management in State of Tennessee facilities only. Its purpose is to provide a concise overview of the mechanical, lighting, and envelope upgrades process. Upgrades may require the expertise of architects, mechanical designers, electrical designers, specifiers, project managers, waste management professionals, maintenance personnel, and financial managers, among others. Each of these disciplines has unique characteristics and complex relationships to the whole process. This manual is not intended to be an exhaustive technical resource for all aspects of the process. Instead, it is intended to provide an overview of the steps and issues critical to implementing successful energy management programs and retrofits. By reference, no guarantee is implied or given on any apparatus manufactured by a specific company. Component descriptions imply intent only, not confirmation of a particular product. Further, though this manual does address the issue of scheduled apparatus maintenance, it is incumbent upon the facilities operations and maintenance managers to exercise their responsibilities in a timely manner consistent with good building management practice.

ABOUT THIS HANDBOOK

This Energy Management Handbook is an important tool in the state energy conservation program. It is designed for facility administrators and building managers of Tennessee state-owned or leased facilities and provides information to accomplish the energy management steps as listed in section 1.2. Following the recommendations in this book should help you to achieve significant energy savings. The energy conservation techniques provided can be used in daily operations and should serve as a reference for your energy management program. This handbook has been divided into three major parts, as follows:

1). ENERGY MANAGEMENT

The Energy Management section provides an overview of how energy can be saved.

2). BUILDING ENERGY AUDIT

In Section 2, you may gather information about your building which will help you decide which recommendations will best save energy at your facility. The building audit forms include space for some information that may or may not be available. It is suggested that they be filled in as completely as can reasonably be done. Much of the information collected will be useful for maintenance and operation as well as energy conservation.

3). RECOMMENDATIONS

Recommendations suggest ways to save energy. This is the largest part of the manual and is broken down by the different energy related systems. These are:

a. Building Envelope

b. Electrical (power distribution, lighting, motors and controls

c. HVAC (heating, ventilating, and air conditioning

d. Energy Monitoring and Control Systems

e. Service Water (service and domestic)

f. Miscellaneous systems

Each of these six units contains a narrative describing major functions of that system followed by actual opportunities for saving energy. The opportunities cited will include operating and maintenance procedures which can be implemented at no cost; minor improvements which will involve low cost; and capital, or major cost, improvements that require coordination with the State Architect's Office. There is a checklist, in Appendix B, of most of the common energy conservation opportunities. Keep in mind, these are suggested energy conservation opportunities. As you go through these, select the ones which are relevant and disregard the ones which do not pertain to the building in question. However, these are not the only conservation opportunities. Innovation and creativity are most appropriate in an energy management program. Each building is unique and it is primarily for the building manager to decide which is best for the building.

Suggestions for additions, corrections, or recommendations for further improving this manual should be submitted to Energy Management Program Office in Property Service Management in Nashville, at 615 741-5973.

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ENERGY MANAGEMENT

PURPOSE OF AN ENERGY MANAGEMENT PROGRAM

Energy conservation became important in the late 1970s and early 1980s mainly due to the 1973 oil embargo. In view of tightening energy supplies and sharply rising costs, new approaches to controlling energy consumption were put into effect. Initially, conservation was largely based on operations and maintenance approaches. These are still the most cost effective. It is important to periodically review buildings to be sure they are being operated and maintained in an energy efficient manner. Building commissioning consists of verification and documentation that all building facility systems perform interactively in an efficient manner and that operation and maintenance personnel are well trained. Energy conservation is an important part of the commissioning process. Energy conservation today involves much more in the way of capital improvements than it did a few years ago. There are many proven products and services available to reduce utility costs. Early energy conservation efforts were sometimes seen as a nuisance to building occupants. Today, many of the improvements being made primarily to conserve energy actually improve the attractiveness, comfort, and usefulness of the building. At today's energy prices, the strongest argument for conservation and an energy management program is the cost of <u>not</u> conserving.

STEPS OF AN ENERGY MANAGEMENT PROGRAM

There are nine steps of an effective energy management program.

a. <u>Obtain total management commitment.</u> Management must encourage and support any program for it to be effective.

b. <u>Obtain employee cooperation.</u> Building occupants are an important element of the building's energy consumption. Their acceptance and support of the program is important, and is best obtained through both education and training. Hence, implement an energy awareness program.

c. <u>Conduct an energy survey.</u> This is the "Building Audit" which identifies building characteristics, energy uses in the building, and how much energy is consumed.

d. <u>Identify problems and solutions.</u> Use information gathered in the audit as well as your knowledge of building conditions, and check the appropriate Energy Conservation Opportunities (ECOs) in each system section. Evaluate the capital ECOs based on life cycle cost. Prioritize capital ECOs.

e. Set conservation goals. Establish a goal in terms of percent reduction or BTU's per square foot, to be achieved by a future date. Prepare and issue an Energy Plan (3 yr. or 5 yr.).

f. Keep consumption records.

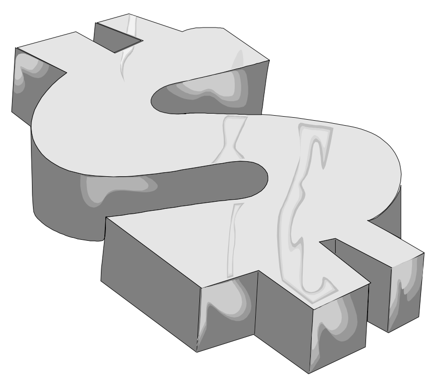
Check monthly utility bills, or make estimates in the case of stored fuels such as coal.

g. Implement changes. Assign responsibility for carrying out the energy conservation opportunities and insure that they are implemented.

h. Monitor results. Periodically compare current consumption with previous energy usage. Check to make sure staff members and building occupants are implementing the energy conservation opportunities. Note any changes in occupancy or schedule that would affect energy consumption, such as adding more people or operating for longer hours.

i. Make appropriate adjustments. Based on monitored results, take appropriate steps to implement any necessary adjustments required by changing conditions.

EVALUATING CAPITAL ENERGY CONSERVATION OPPORTUNITIES (ECOs)



Capital ECOs are generally considered to be those costing over $1,000. This is a somewhat arbitrary designation. In a large facility, some items costing more may be paid for from operations and maintenance funds and be considered low cost. In a small facility improvements less than $1,000 may require further study. In any event, capital improvements need to be evaluated using life cycle cost techniques. Determining simple payback (cost divided by annual saving) is a useful screening tool, but it does not take all factors into consideration and may eliminate some cost effective long term improvements. The NIST " Building Life-Cycle Cost" (BLCC) Program, Sponsored by The Federal Energy Management Program, U.S. Department of Energy, is very useful for this type of analysis. Obviously, accurate cost and saving data is essential to meaningful results. It is recommended that capital ECOs be evaluated by licensed professional engineers, architects, or energy management professionals who specialize in energy conservation.

HOW MUCH ENERGY CAN BE SAVED

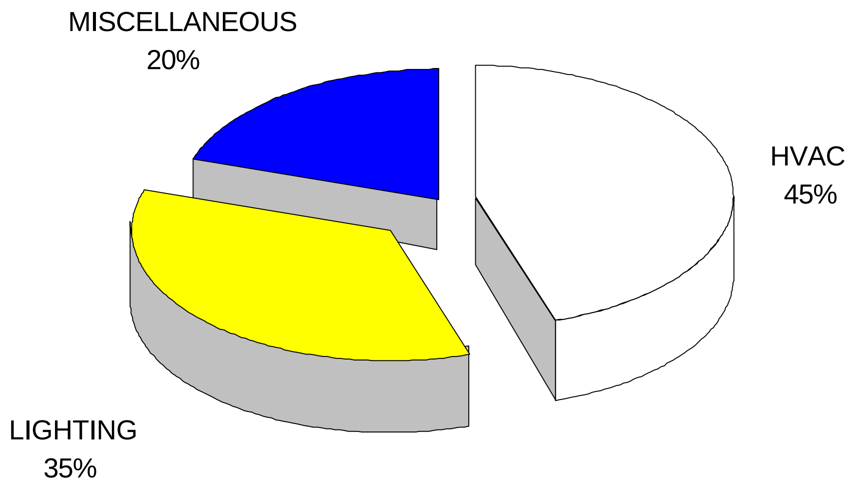
Perhaps your next question is, "How much energy can be saved?" The following is a list of several measures with their estimated energy savings.

Energy Conservation Opportunities	Estimated Energy Savings*
Turn back temperature to 68° in winter	5% of heating cost for each degree set back
Turn up temperature to 78° in summer	3% of cooling cost for each degree raised
Maintain furnace at maximum efficiency by annual checkups and adjustments	10% of heating cost
Maintain air-conditioning units by annual checkups and adjustments	15% of cooling cost
Set back domestic water heater from 140° to 110°	6-12% of hot water cost
Maximize use of daylight	50 - 60% of lighting cost
Improve lighting maintenance	10% of lighting cost
Turn off unnecessary lights	17% of lighting cost
Reduce lighting	15-28% of lighting in existing buildings 25-50% of lighting in new buildings
Use insulating glass	10-13% of cooling and heating costs
Insulate hot water pipes and storage tanks	15% of water heating costs
Provide adequate insulation for wall and roof	20% of heating and cooling cost

** % saving is estimated value, the saving varied depend on different cases*

ENERGY USE IN TENNESSEE BUILDINGS

The following is a diagram showing the major energy systems with the percentage of energy consumed in a "typical" Tennessee building. The percentages vary greatly from building to building. The chart below shows the energy use in a "typical building" based on experience from a large number of buildings in the southeast. Many factors affect the way energy use is distributed. A building with a large miscellaneous load will have less heating load than "typical," but may have more air conditioning load. Newer more efficient buildings will use less energy for both HVAC and lighting than older buildings, but the lighting energy use will be larger compared to the HVAC in the more efficient building.



TYPICAL BUILDING'S ENERGY USAGE

OPERATION AND MAINTENANCE

One of the most effective ways to save energy is to improve operations and maintenance. In many buildings it is possible to save ten to thirty percent of the energy usage by changes in operation and maintenance. In the sections that follow many of the recommendations involve operation and maintenance. This section covers a few general items that are not covered in the discussion of specific systems.

CUSTOMIZED OPERATION AND MAINTENANCE MANUALS

Operation and maintenance manuals are essential to an efficient building. These may consist of manufacturers manuals on equipment and building specific manuals. The size and complexity of a building will determine the level of detail. Equipment that is maintained on a regular schedule tends to operate more efficiently as well as more reliably. Simple schematic drawings to quickly determine approximate values of temperature or airflow can help find out if systems are functioning properly**.**

CUSTOMIZED OPERATION AND MAINTENANCE LOGS

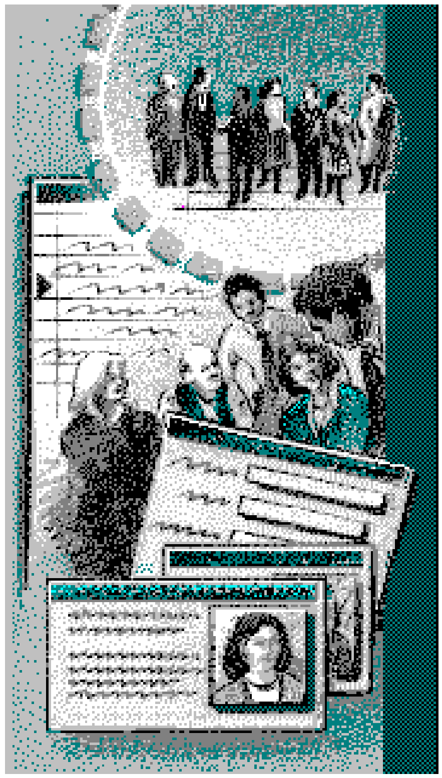
Logs are important to determine when maintenance was performed and the function of the equipment. In order to perform analysis on the building it is important to be able to know the operation of the equipment.

TRAINING OF OPERATION AND MAINTENANCE STAFF

Proper training of the operation and maintenance staff is important to the efficient operation of the buildings and building systems. This is particularly true in buildings with energy management systems and other sophisticated controls. The use of video tape can help ensure new staff quickly learn systems. On site descriptions of how equipment operates can be provided by equipment manufacturers.

PROCUREMENT OF ENERGY EFFICIENT REPLACEMENTS

The best planned program of energy conservation will soon be thwarted if replacement parts and consumable are bought on a lowest initial cost basis with no regard to efficiency. If energy efficient replacements are purchased and stocked for such things as lamps and ballasts, inefficient equipment can gradually be upgraded to more efficient with very little additional cost. The Department of General Services is working to increase the number of products available through central purchasing methods such as Central Stores.



ENERGY AWARENESS PROGRAM

A program to make not only the operation and maintenance employees, but also the building occupants, aware of the importance of saving energy can contribute to the overall efficiency. Tenant meetings offer a good opportunity, not only for increasing awareness, but also to give vital operational feedback to managers. Recognition for accomplishments can build morale and make everyone feel a part of an improved systems approach.

BUILDING ENERGY AUDIT

WHAT IS A BUILDING ENERGY AUDIT?

An energy audit is a critical examination of the energy consumption of a building. The audit consists of an analysis of each type of energy consumption, cost and demand for at least a twelve month period, and an on-site, walk though examination of the building shell and energy consuming devices in the building. The purpose of the Energy Audit is to identify specific energy conservation opportunities (ECOs).

PLANNING FOR ENERGY AUDITS

Energy utilization can be improved in any building. Obviously some buildings are better performers than others. To better utilize available funds it is prudent to look at which buildings are the worst performers or heavy energy users, such as hospitals or buildings requiring 24 hours/day operation, and audit them first with the idea of capturing shorter paybacks on implemented ECOs.

This can be done best by studying records of energy consumption for the past several years (making judgments and allowances for major changes, such as more or less personnel, a major addition or major modification). Energy usage should be collected by someone on the building management staff specifically assigned this responsibility. The energy consumption data is obtained from the utility bills which can be found in the bookkeeping or accounting office of your facility or department, or directly from your utility company. In a large facility or complex of buildings, it may be well worth having a full time energy manager or someone that has part of their work time specifically devoted to energy conservation.

The energy use tables in Appendix A -13.0 may be used to collect three years of energy data. Total annual consumption's of all types of energy may be converted to thousand BTUs (KBTU) using the following conversion factors:

Energy Type	***Quantity***	***Unit***		***Conversion Factors***		***10^3 BTU's***
Electricity	____________	KWH	X	3.413	=	____________
Natural Gas	____________	CCF	X	100	=	____________
Coal	____________	Tons	X	25,000	=	____________
Oil (#2)	____________	Gallons	X	138	=	____________
LPG (Propane)	____________	Gallons	X	91.6	=	____________
Steam	____________	Pounds	X	1.0	=	____________
Chilled Water	____________	Ton Hrs	X	12	=	____________

AVERAGE PERFORMANCE FOR STATE OF TENNESSEE BUILDINGS

The following chart shows building energy use averages, in BTU/square foot per year, for Tennessee State Buildings. You can compare your building's energy use to see how it compares to the average situation.

Type of Facility	Tennessee Buildings Energy Consumption	DOE Survey Energy Consumption**
Office, Administration	65,000*	95,500
Elementary School Building	70,000	64,900
Secondary School	60,000	64,900
College Classroom	83,000	64,900
Gyms and Auditoriums	68,000	56,400
Food Preparation, Cafeteria	211,600	231,700
Hi-Rise Dorm	106,000	82,800
Apartment	53,000	82,800
Mobile Units	84,000	N/A
Hospitals	226,000	154,000
Clinic / Long Term Health Care	72,000	82,800

**116,000 BTU/sqft/year reflects large computer or process loads not typically found in most state office buildings. A figure of 65,000 BTU/square foot is more representative for office buildings without large computer or other process loads where reasonable conservation measures are implemented.*

*** The data was compiled by DOE in 1989 printed in 1992 for south region commercial buildings categorized by buildings activity. (Ref. 15, Table 16)*

NOTE: These are average numbers and may not be a realistic goal for a particular building. The hours of use vary from building to building and will affect energy use.

CALCULATING THE ENERGY UTILIZATION INDEX (EUI) FOR YOUR BUILDING

Following are the steps required to determine the energy utilization index:

a. Select the appropriate facility-type for your building from the preceding table.

b. Divide the total annual BTU/sq. ft. from the Energy Use Charts by the corresponding value from the preceding table to get your (EUI) building performance measure. For example, consider a 50,000 square foot office building with typical office equipment, that uses 3,000,000 KBTU of energy per year.

3,000,000 KBTU/year / 50,000 square feet

= 60 KBTU/ square foot/year

E U I = 6 0 / 6 5 = 0 . 9 2 3

Using the recommended 65 KBTU/year/square foot for a simple office building

c. If your EUI is less than 1, your building energy use is less than the average for a comparable Tennessee building. If your EUI is greater than 1, your building's energy performance is more than the average for a similar type building in Tennessee and a detailed audit is probably needed to find what energy uses can be reduced within budgetary allowances. In the example, under item b above, the building would not be assigned a high priority for an audit. It should be noted that every energy saving idea or device will not pay back in the monetary cost of energy in the lifetime of some buildings while others will payback in a few years. In addition to dollars payback, of course, there is the added environmental benefit of reduced thermal and toxic gaseous emissions due to reduced need for energy production. Those energy conservation opportunities (ECOs) that have the best paybacks (on the order of 5 years or less) are recommended to be implemented as soon as possible. However, if some improvements (such as lighting or general renovation) are scheduled to be done anyway, or if a combined number of ECOs provides a good payback and they improve productivity in the workplace, comfort and/or aesthetics, it may be justifiable to proceed with them. In every case, indoor air quality issues must be considered. In particular any modifications to heating, ventilation, and air conditioning systems and their associated controls must not degrade the indoor air quality or violate code requirements for fresh air. Consultation and advice is available from the Energy Management Program.

Sample energy conservation opportunities (ECOs) check lists are provided in Appendix B to enable you to establish an energy conservation program in your building(s). Note that many of these are low cost or no cost operations and maintenance procedures.

If you need assistance in evaluating opportunities or setting up a program, contact the Energy Management Program Office in Property Services Management in Nashville, at (615) 741-5973

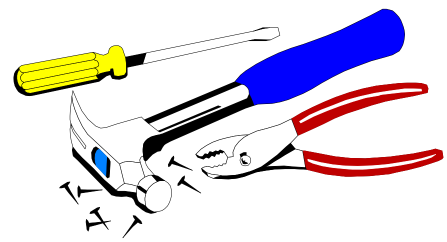
SOURCES OF AUDIT INFORMATION

Several persons will need to be contacted to obtain the required information. The building manager with several maintenance personnel should fill out the detailed audit forms as completely as possible. In some instances a detailed audit by energy management professionals will be required prior to analysis of the more technical ECOs. Completeness of the data forms will greatly assist the energy management professional team and will reduce data collection costs. Since energy retrofits frequently improve the quality of the workplace and reduce operation and maintenance problems, it is wise to be as thorough as possible.

MATERIALS NEEDED

Certain materials are necessary and helpful when doing an energy audit. As-Built building plans (architectural layout, electrical, and HVAC/mechanical) are very useful.

Other useful items include:



1. light meters
2. flashlights
3. measuring tapes
   (may need a 15'-25' and 100')
4. electronic measurement device (nice for ceiling heights)
5. calculator
6. thermometer
7. vane anemometer or hot-wire device for measuring airflows
8. screwdriver with combination flat/Phillips points
9. camera and film
10. an ammeter if you intend to check loads on some equipment

Safety items should be used where needed. These items may be available at the job site but call ahead to be sure. These may include the following:

1. hard hats
2. safety glasses
3. ear plugs

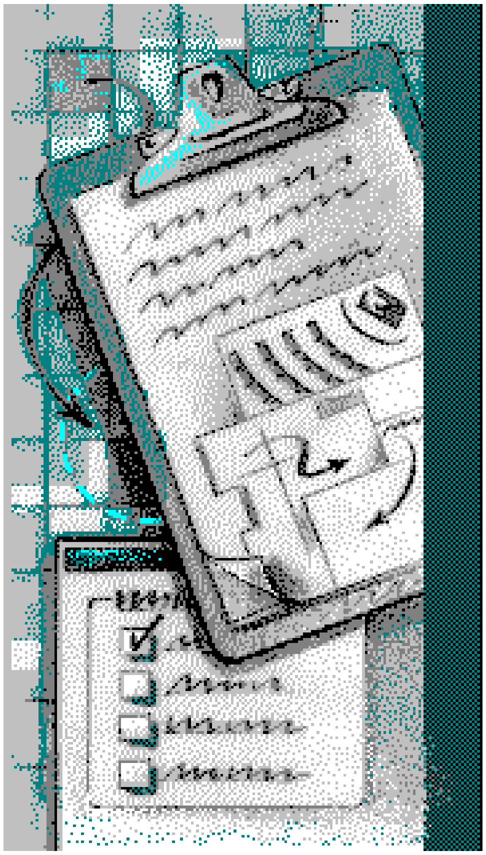
Other items might include:

1. an inspection mirror for reading numbers on equipment which are out of sight
2. extra batteries for the battery powered equipment
3. a magnifying glass for reading small and almost worn out numbers on equipment
4. a clipboard and extra scratch paper
5. rags (it may be dirty in places and these are helpful in wiping machinery nameplates to read data)
6. a carrying bag or case for equipment
7. step ladder (this may be available at the facility)

BUILDING CONSTRUCTION AND USE

If at all possible, obtain a copy of the building plans which show the original construction and modified details and dimensions. It is necessary to check the information on-site, by walking through and inspecting the building. If the building plans cannot be obtained, all the information can come from your walk-through audit. Note: Emergency Evacuation Route Plans or Floor Layout Plans for location of offices and personnel can be very valuable walk-through tools to assist in collecting data, and locating and describing ECOs.

While walking through the building, you should take notes on the physical condition of the building. In particular, note any leaks, broken windows, missing insulation, or operational problems that exist. If your building has special areas that are not covered in this section, they should be documented here (for example auditoriums, gymnasiums or cafeterias). The information you collect in this section will be the basis for choosing energy conservation opportunities to be implemented immediately (low cost or no cost ECOs) and those that require payback analysis by the Energy Management Program or their contracted energy professionals.



DATA COLLECTION

Forms are designed to allow data collection to a detailed level if time, budget, and other activities allow. Detailed data is necessary if verifiable calculations are to be made on ECOs. Such calculations do not need to be made by those collecting the data. A good job of data collection by the building managers, staff and O & M personnel can greatly reduce the cost of data collection by energy calculation professionals and will often produce excellent results because the persons operating the building usually are very familiar with their building and systems.

If the building is small and/or the estimated potential savings is not great, all data will not be applicable and some data will not need to be collected. Consult the State Building Energy Management Program Office, if you have questions about what is pertinent to your building.

The forms in Appendix A are designed for use in collection of general building information and detailed data in three major areas:

1). Building Envelope

2). Electrical Systems (Lighting is the major division)

3). Mechanical Systems

Note that mechanical and electrical systems overlap somewhat and data for electrical ECOs may be collected on data sheets for the mechanical equipment that is heated or driven by electricity, e. g., motors and resistance heaters. In these cases motor efficiencies and heater element sizes are collected on the mechanical equipment data sheets.

Lighting is an electrical specialty that is unique and has separate data sheets.

BUILDING ENVELOPE

Energy use in buildings is affected not only by electrical and mechanical systems, but also by the building envelope or shell. Heat is transferred out through the building envelope in winter, and into the envelope in summer.

The building energy audit should identify some of the problems associated with the building envelope. Three major contributors to energy inefficiency in the building envelope are: (1) infiltration and exfiltration of air, (2) solar radiation heat gain through windows, and (3) conduction heat loss through windows, walls, floors and roofs.

INFILTRATION AND EXFILTRATION

A large portion of the energy required for heating and cooling a building results from the heat gains and losses through the building envelope. The major part of this is infiltration and exfiltration-air leakage through openings around windows and door jambs, doors and windows left open, and outside air vent dampers which do not close tightly.

Building materials greatly affect the amount of heat loss or gain due to infiltration or exfiltration. The number of windows and doors will also influence this effect. Caulking materials can range from good to poor and can change in quality over a period of time.

There is a stack effect in tall buildings, especially in spaces such as stairways, elevators, and mechanical service shafts. Since warm air tends to rise, when outside air is cold there is a strong potential for infiltration at the bottom floors and exfiltration at the top.

Wind pressures also influence the infiltration/exfiltration of air in a building with infiltration on the windward side and exfiltration occurring on the leeward side.

Keep in mind that no building is an air tight box, thus infiltration basically equals exfiltration with the exception of some slight pressurization effects caused by some HVAC systems that intake slightly more fresh air than the exhaust fans exhaust.

Not all infiltration and exfiltration is bad, since a minimum amount of fresh air is required in all buildings to maintain good indoor air quality (IAQ). ASHRAE 62-89, it’s 1990 amendments and its successors, should be used as the basis for controlled intake and exhaust air. Ideally such air should come through a heat exchanger to minimize energy losses. Secondly, it should be conditioned and well distributed by the heating/cooling coils and circulation system to avoid discomfort zones.

In small buildings with a few occupants, enough outside air may be supplied by normal well-distributed infiltration/exfiltration through cracks and normal operation of door openings. The ASHRAE 62-89 ventilation standard recommends 15-20 cfm per person for an office type building in lieu of monitoring for safe levels of expected harmful gases. Some larger buildings, sized for 50 or more persons, have been built or modified to have no controlled exchange of outside air. Care must be exercised in extreme tightening of these buildings without provisions for cleaning or adding fresh air exchanges. If questions arise about the effect on indoor air quality due to tightening of the building envelope, the representative for Energy Management Program should be consulted.

CAULKING, WEATHERSTRIPPING, AND STORM WINDOWS TO REDUCE INFILTRATION/EXFILTRATION

Airflow heat losses and gains through the building envelope can be minimized by caulking, weather-stripping, or installing storm windows. Caulking between fixed openings, and weather-stripping of moveable window sashes and doors are the major means of reducing heat loss. There are many types of caulking and weather-stripping materials. In general, the non-hardening, surface-skinning types of caulking are best. Caulking material must be permanent and should be chosen according to the surfaces involved. Surfaces must be clean and dry. For wide cracks, a filler or backer-rod must be used. Weather-stripping includes compressible, closed cell foam, compressible "tubular" systems, and interlocking metal strips. Since there are so many different conditions which can exist for caulkings and weather-stripping, it is wise to get expert advice on the subject from, for example, caulking and sealing contractors.

Storm windows are often used to increase the amount of thermal resistance through glass. Double glazing (2 panes of glass in the same frame) can be used to reduce the heat loss of single glazing by one-half. However, storm windows have three advantages:

1). They improve control of outside air intake by reducing leakage of air around the window frames.

2). Storm windows in a second frame are usually more energy conserving than double glazing in a single frame. Using low emittance glass for storm windows can further lower the heat transfer.

3). They are generally easy to install (depending on the physical condition of the existing frames, the present needs, and replacement plans for each building).

SOLAR RADIATION HEAT GAIN THROUGH WINDOWS

Solar heat gain through windows can have a major impact on energy use. The amount of solar heat gain depends on:

1). the orientation of the building

2). the type of window treatment.

The effects of the building's orientation are different for winter and summer. In winter, the sun movement allows a little east and west wall solar heat gain in the morning and afternoon, and a lot of mid-day sun on the south walls into south facing windows.

In the summer, solar radiation is more severe on the eastern and western sides and not so serious on the southern wall. North facing walls and windows get no sunshine in the winter and only early morning and late afternoon angular exposure to the sun in the summer.

WINDOW TREATMENTS TO REDUCE SOLAR RADIATION EFFECTS

Shading must relate to the sun's orientation. Emphasis should be on shading the south, east, and west windows in the summer, and allowing the solar heat gain in the winter.

Internal shading devices include drapes, venetian blinds, vertical louver blinds, roller blinds, and variations of these basic types. While less effective than external devices for control of solar heat gain, internal shading devices have several advantages. They are relatively inexpensive, and are easier to adjust to the desired amount of solar gain, light, and view. Controlling the solar gain will reduce the need for HVAC.

External shading devices are the most effective method of controlling solar heat gain because they prevent the sun from shining directly on the glass. Tinted or reflective glass or polyester films (which are either tinted or reflective) can be applied to the inside of the glass to reduce solar heat gain. The tinted or reflective glass can be used to replace existing glass or to create double glazing by installing storm windows. The films are self-adhesive but require special care in application. Exterior fiberglass louver mesh sunscreen can block solar heat by 70 %, and it can be installed at moderate cost.

The entire year must be considered from a total energy standpoint when determining payback for fixed shading and reflective devices. Although these devices may be justifiable from a comfort standpoint in summer , the loss of desirable heat gain in winter may negate energy savings.

CONDUCTIVE HEAT TRANSFER IMPROVEMENTS THROUGH WINDOWS, WALLS, ROOFS, AND FLOORS

In energy conservation, a major concern is the distribution of heat flow through different types of building construction. The rate of heat loss through the building envelope is dependent on the structural materials and the type and thickness of the insulation used. The thermal resistance of a material is its R-value. R-value is meaningful in discussing the improvements that might be achieved by the addition of certain insulation materials. These materials are commercially rated by their R-values. Remember, the higher the R-value, the better the "insulation" value.

In addition to conductive heat flow through a material, heat is reflected by radiant surfaces. Some insulation materials use both properties while others rely mostly on one property. A recent demonstration showed that a newly developed radiant barrier placed in the area above the drop ceiling at the underside of the roof surface will save energy and provide a reasonable payback. If there are few obstacles involved in the space between the roof and ceiling, such "heat barriers" may have a distinct ease of installation and cost advantage over conventional insulation.

The basic materials found in wall and roof construction are inadequate by themselves as thermal barriers. As a result, different amounts and types of insulation are included in the building design. Part of the physical examination of the building envelope, in the basic energy audit of the building, is an analysis of the plans, details, and specifications of its construction to determine the resistance to heat flow of its many parts. On a national scale, it is estimated that 20% of all energy use is for space conditioning in buildings. Of this, 25% results from heat losses and gains due to the relatively high thermal conductivity of windows, an energy use equivalent to an average of 1.7 million barrels of oil a day. Therefore, the effects of heat loss/gain through windows and the building envelope are considerable and should be evaluated from this perspective.

SUMMARY

A large portion of a building's heating and cooling requirements are due to heat losses and gains through the building envelope due to infiltration, exfiltration, and heat transmission through surfaces. Solar heat gain can be used during the winter to lower the heating load, but is generally unwanted in the summer. To decrease the unwanted effects of heat gains and losses, caulking, weather-stripping, and different types of window treatment can be applied. By implementing these measures, the building envelope becomes a major area for lowering energy consumption, and the chiller size may be downsized when the chiller needs to be replaced. Operations and maintenance items are the most economical to implement. Items such as, caulking, repairing door and windows closures, often provide excellent paybacks.

Even though envelope improvement can save a great deal of energy, care must be taken in performing major envelope improvements to the building windows, doors and insulation to ensure economic paybacks within the useful life of the building. Typically, adding insulation in Tennessee buildings with little or no insulation will result in paybacks from ten to fifteen years. Paybacks on storm windows usually are on the same order of time. An airlock on a heavily used door may provide a payback on the order of five to ten years. Because adding roof insulation can be very expensive and often disruptive if performed on the inside of the building, it is recommended to seriously consider adding insulation and/or radiant barrier at the next re-roofing job when it can be installed at a fraction of the labor cost and will be more effective. If the effect of the chiller downsizing is taken into account, the payback period may be reduced.

Before making capital improvements to the envelope for energy purposes, you should consult the Energy Management Program to verify expected paybacks, or to provide estimated paybacks.

ELECTRICAL

The major source of energy for many buildings in Tennessee is electricity. Traditionally this area has had cheap, abundant electrical energy. Consequently, many buildings and systems were designed with little regard to electrical usage. It is important to understand the factors that affect the cost of electricity in a building.

Electrical demand is measured in kilowatts (KW). This is the largest amount of power used during a given period of time. A typical rate structure would define the monthly demand as the highest average power usage during any 15 minute interval during the month. Usually the customer is billed for about $10.00/KW. Smaller buildings below 50 KW pay no demand charge. Some rates may include a minimum demand charge based on a percentage of the highest demand recorded during the past year.

Electrical energy is measured in kilowatt-hours (KWH). As the term implies, this is the product of power (kilowatts) and time. This is the reading of the typical electric meter.

Energy and demand are the two items that usually determine the electric bill. In addition, power factor sometimes has an important impact on the electrical cost.

Power factor is defined as the ratio of real power to apparent power. Induction motors, fluorescent lighting and high intensity discharge lighting produce inductive reactance which causes the current in the electric system to lag behind the voltage. For more information on power factor, contact your local power distributor.

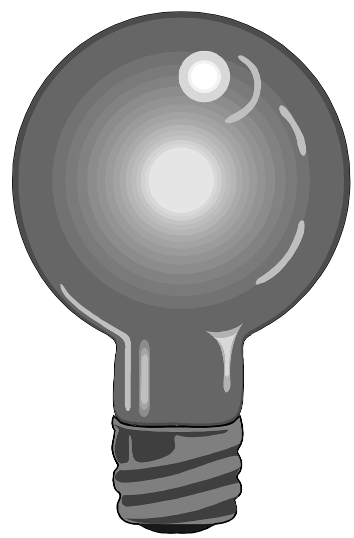
It is important to understand how the electric bill is determined. This alone can often save money, if not energy. For instance, in a building with chillers, peak electrical demand may occur only a few minutes during the month, but this usually affects the monthly bill drastically due to peak pricing penalties. Also, in some cases, it may be possible to switch to a more favorable rate (e.g., if paying for a peak load capability that is not needed).

Except in buildings that are heated electrically, lighting is often the major user of electricity. Lighting is the most significant contributor to the internal heat gain in office buildings, causing the air conditioning to operate with a heavier load.

Electric motors can be a significant user of electricity. In many state buildings most of the motors will be found in heating and air conditioning equipment. A few buildings may have processes that require a large motor load.

In addition to lighting and motors there are some miscellaneous items that can be changed to improve electrical efficiency and these are discussed under the miscellaneous section.

LIGHTING



Lighting requirements have changed over the past several years due to several factors. First, is the widespread use of computers. Lighting requirements for an office with heavy computer use are quite different from those in an office doing the same tasks manually. Often it is desirable to have much lower background (ambient) light levels than have been common in the past. Also, reflections on computer screens have increased the need for lighting changes. Equipment improvements have made possible some significant energy saving opportunities that were not available a few years ago. Recommended practice in the Illumination Engineering Society (IES) Lighting Handbook is generally considered to be the standard to which lighting is designed. The Illumination Engineering Society, since 1981, has published a range of recommended light levels for various tasks. A number of factors affect the actual level selected. The net result of all these changes is that many lighting systems in buildings designed 15 to 20 years ago provide more light than is needed by current standards.

There are some terms peculiar to lighting that need to be understood to compare the various type of light sources:

> <u>Lumen</u>- This is the most common measure of light output. Light sources are rated in lumen output. This factor is used to determine if two light sources are comparable. For example in substituting compact fluorescent lamps for incandescent, it is important that the lumen output of the two be about the same to keep the same light level.

Foot-candle- Light intensity on a plane at a specific location is measured in foot-candles. Foot-candle is a ratio of lumens per square foot. Foot-candles are usually measured on a specific work surface such as a desktop or floor.

Color Rendering Index (CRI)- The color appearance of an object under a light source, as compared to a reference source is the color rendering index. CRI is a relative scale ranging from 0 to 100. This number is important in comparing light sources where color is important. The higher the number the more accurately colors show up under the light source. The CRI of an incandescent lamp is 100.

Efficacy- Efficacy is a measure of the effectiveness of a light source. The word efficiency is not used because light output is not measured in the same units as the electrical energy input. Efficacy is the ratio of lumen output to watts input. The higher the efficacy, the more efficient the light source.

Luminaire- Light fixture

LIGHTING MANAGEMENT

A lighting management program provides a means to control the amount of light used at any given time. The major advantages of such a program are that it can be tailored to the individual characteristics of the space and to the needs of its occupants.

Key elements in establishing an effective lighting management program are listed below:

- Determine the amount of lighting needed for safety and security purposes
- Define the exact type of occupancy for each period of time.
- Schedule the lights to be on only when needed except security or emergency lighting.
- Assign responsibility for the lighting management.
- Provide detailed instructions for the program to responsible employees by means of charts, posting of instructions, and color coding of switches.
- Be sure operation and maintenance instructions consider energy efficiency
- Procure energy efficient lamps
- Identify persons responsible for good lighting management

MEASURING ILLUMINATION LEVELS

Illumination has traditionally been measured in **foot-candles**. Lighting levels can be surveyed with a light meter to determine their current intensity. Measurements should be made at many representative points to obtain an average of several readings. Condition and age of fixtures should be considered. Initial light levels with a new system will deteriorate over time due to dirt and aging of the lamps and luminaires. Daylight should be excluded during illumination-level readings for a true determination of level. Ideally, surveys should be made at night. For initial determinations, it is usually sufficient to conduct surveys on overcast days, or to measure with lights on, and again with them off, and subtract out the daylight component.

SIMPLE CONVERSION OPTIONS

The following sections are discussions of low cost conservation opportunities for lighting. The major opportunities discussed are:

IMPROVED MAINTENANCE

There are two major maintenance considerations affecting lighting efficiency. First, lamps decrease in efficiency over time and should be replaced before they actually burn out. Second, dirt builds up on lamps, reflectors, and lenses thereby reducing the amount of light output from the luminaire. There are two basic approaches to lighting maintenance, spot relamping and group relamping.

With spot relamping, lamps are simply replaced when they burn out or lose enough of their light output to be a problem. This approach works well where there are only a few lights and the maintenance is done by building employees. However, it is more costly over time because ladder or other equipment must be carried each time a lamp is changed.

Group relamping, the replacement of all lamps in a system regardless of the number of failures, is often used where there are a large number of lights. Maintenance may be done by state employees or it may be done on a contract basis. Typically group relamping is done at about 70% of rated lamp life. For example, if the lamps are rated at 20,000 hours in the vendor's catalog, and the lights are used 2600 hour per year the replacement cycle is about

20,000 / 2600 X 0.7 = 5.4 years

A few spot replacements are sometimes necessary due to random failures, if they occur in areas where full light level is needed. Group relamping can sometimes aid in efficiency, because if a system is well maintained it may be possible to use fewer or smaller wattage lamps.

Any maintenance program should include regular cleaning of the luminaires. This is most easily accomplished during group relamping since it can be included with the relamping procedure. Depending upon operating conditions, cleaning may need to be performed more often than group relamping.

USE OF DAYLIGHT FOR LIGHTING

Windows can be used effectively as a primary source of lighting. It costs nothing to manually turn off lights when there is sufficient daylight. Photocell controls that automatically switch off the lights are often inexpensive to install. More sophisticated controls are discussed in Section 4.1.4.4. There are several factors that determine the amount of daylight that can be used.

a) The building operating hours.

b) The weather.

c) The time of year.

During the winter, the additional heat gain from the windows is helpful in reducing the need for heating energy. In the summer, the illumination is beneficial, but the heat produced will increase the air conditioning load.

d) Shading devices.

Drapes, blinds or window tint can be used to control daylighting. Blinds and drapes can be closed to eliminate glare during periods of direct sunlight. They can be opened when indirect daylight can be used for lighting. Window tint in the form of tinted glass or added film can be effective in reducing glare and heat gain.

e) Window size, location, and orientation

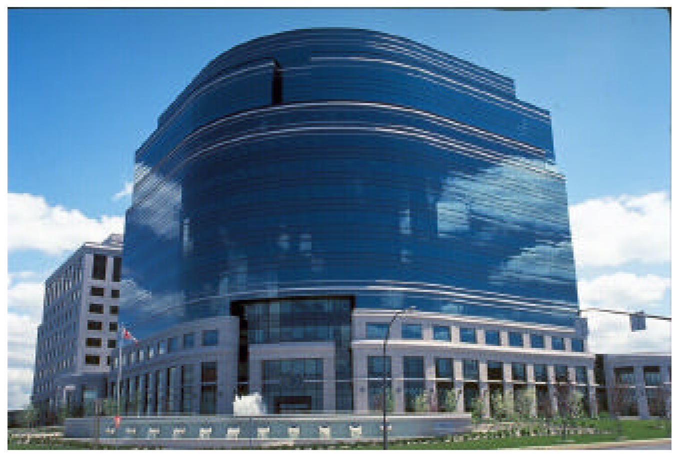
Windows on the east, south, and west will receive almost all of the available sunlight. However the north sky, even on overcast days, can contribute a substantial amount of daylighting. Windows located on the north side are often the best for daylighting in office buildings where glare control and uniformity are important.

f) Color of interior surfaces.

Lighter colored walls, floors, and furnishings will assist in adequate light reflection.

g) Location of people and desks

Generally it is possible to use daylight in the 15 feet around the perimeter of a building. Spaces farther into the core do not usually receive sufficient light to be effective. Desks or work surfaces should be perpendicular to the windows so that the light is provided from the side. People should not be facing the window. Light coming from behind is particularly annoying to computer users, because it tends to reflect off the screen.



Daylighting is most effective in areas where wide variations in light levels can be tolerated. It can be aesthetically pleasing when used in circulation areas. It is also quite effective in cafeterias and break rooms if care is taken to control glare. Daylighting in office areas is challenging to do effectively. If glare or direct sunlight is a problem, employees will usually close the blinds or drapes and resort to artificial light. However, if the problems can be controlled, it can make the environment more pleasant. Some experts even claim that it increases productivity. New products can automatically raise or lower light output to maintain the proper light levels. Ask the Energy Management Program for more information

REDUCING LIGHT LEVELS

Energy can be saved by reducing illumination levels and eliminating lighting that is not needed. If several tasks that require different levels of illumination occur within a space, you can rearrange the area while reducing illumination levels to the appropriate level for each task. A uniform modular lighting pattern, throwing light equally on all areas regardless of task may waste up to 50 percent of the energy used for lighting in the building. Orient lighting to suit the tasks being performed.

If one task with a high-level lighting requirement is confined to a specific work area (for example, a drafting table, typewriter, or a desktop) provide lower general illumination and a task light for each critical task to raise the level of illumination for that area only (use fluorescent lamps in preference to incandescent). In many cases it is less costly to move tasks to suit an existing lighting pattern than to add or rearrange fixtures. If task areas are widely dispersed, more light spills into adjoining areas where it may not be needed. Group together those tasks requiring similar lighting levels to limit the spill of higher level illumination, and to allow lower levels at less demanding work areas.

REMOVE UNNECESSARY LAMPS / RELAMP WITH MORE EFFICIENT LAMPS

Remove unnecessary lamps when the ones remaining can provide the desired level of illumination. When removing fluorescent lamps or high intensity discharge lamps, remember to remove or disconnect the ballast. If it is left connected, it will continue to use energy even though it serves no useful purpose. Four-lamp fixtures can often be delamped to two lamps. When two-lamp fluorescent fixtures are mounted in rows remove lamps in alternate fixtures of the rows (rather than removing an entire row) to derive higher quality lighting. Sometimes it is necessary to use increased output lamps to compensate for delamping. For example, four-lamp fixtures designed to operate with four T-12 lamps can often be operated with two T-10 lamps to provide sufficient light, while saving about 76 watts per fixture.

Lamp efficiencies vary between lamps consuming the same number of watts, and lamps of the same type. Different colors, shapes, gaseous fills, cathode and internal coatings cause these variations. For example a fluorescent 40 watt T-12 lamp can have a rating from around 53 lumens to around 82 lumens per watt. Or for example, a natural white color fluorescent lamp at 53 lumens per watt provides one-third less foot-candles than a cool-white fluorescent lamp of the same or higher wattage. In some cases it may be desirable to relamp with lower wattage lamps as an alternative to removal of lamps.

More efficient lighting imposes smaller heat loads on the air conditioning system. Lighting is not an efficient way to heat a building. Unless electric resistance heat is being used, it is generally much more efficient to supply needed heat with the heating system than the lights.

USE APPROPRIATE LAMP TYPES

Incandescent lighting is the least efficient. Unfortunately, it is usually not a simple matter to convert from one type of lighting to another. There are some exceptions that are worth considering. The more expensive conversions are discussed as capital improvements in Section 4.1.4. Compact fluorescent retrofits are made in many configurations to convert from incandescent to fluorescent. These are available as integral lamp and ballast assemblies or with separate lamps and ballast/adapter assemblies. They are also available with reflectors to concentrate the light in one direction. These are especially useful in downlights.

Exit signs using light emitting diodes (LEDs) can significantly reduce the energy used. Although, incandescent lamps used in exit signs generally require less than 25 watts per lamp, there can be a significant number of them and they are operated all the time. In addition to energy cost, it is troublesome and expensive to replace lamps. Signs using LED technology are expected to last 80 years or more, virtually eliminating maintenance costs. Signs using LEDs are recommended for new installations and as replacements for existing signs. Where existing signs are in good condition retrofits are available.

TURN OFF UNNECESSARY LIGHTS

At one time it was common to leave fluorescent lights on, because it was believed to be cheaper to use the energy than to shorten the lamp life. This may have been true thirty years ago when electricity was cheap, but it is no longer valid. The lights should be turned off in any area that is going to be vacant for more than a few minutes, unless it is needed for security or other reasons. It may actually increase the useful life of a fluorescent lamp to turn it off when not needed. This is why. A typical lamp may have a rated life of 20,000 hours. When operated 8 to 10 hours at a time, life increase to on the order of 24,000 hours. Increasing the number of starts will reduce the number of hours the lamp can be burned. However if it is off a significant part of the day, the actual calendar life may be increased because the lamp does not burn all day. The simplest thing to do is to regularly turn off lights when leaving an area. This is not always practical and people do not always remember to do so. Several low cost devices are now available to do this automatically.

Simple twist timers are the least expensive. They can be used very effectively in fairly small areas that are infrequently used, such as storage closets. New electronic timers can be set for a preferred time delay with a simple override feature for use in mechanical equipment rooms. Several types of occupancy sensors are available. A simple passive infrared type that replaces a wall switch is relatively inexpensive and easy to install. Occupancy sensors are usually effective in restrooms, but ultrasonic types work best in this application. Caution should be used where there is a possibility of an accident if the lights are turned off by an automatic device, such as around machinery or in large areas where a person may not be able to see to get out. In those cases safety takes precedence over efficiency. Often the best choice is to activate only certain fixtures with the automatic controls.

CAPITAL ENERGY CONSERVATION OPPORTUNITIES(ECOs)

Many energy conservation opportunities (ECOs) cost enough to be classified as capital projects. It is impossible to list all the lighting improvements that could be used to improve efficiency. Several of the more common ones are included in this section. It is recommended that a thorough audit be conducted and an economic analysis be done before embarking on any major lighting changes. A lighting or energy professional should be consulted.

T-8 LAMPS AND ELECTRONIC BALLASTS

INTRODUCTION

Electronic ballasts are the electronic high frequency equivalent of a conventional core and coil (electromagnetic) ballast. These ballasts have been produced for several years, but only within the last few years have they become widely used. Electronic ballasts have a higher efficacy than electromagnetic ballasts. T-8 lamps are smaller than T-12 lamps and have a higher efficacy and produce a higher quality light (higher CRI). For example an electronic ballast can operate two 32 watt T-8 lamps at full output using about 58 to 60 watts. The reason for this seemingly impossible situation is that the electronic ballast operates the lamps at a high frequency (about 20,000 Hz as opposed to 60 Hz for core and coil ballasts.) This enables the lamps to produce light more efficiently.

ADVANTAGES

The main advantage of T-8 lamps and electronic ballasts is the reduction in energy consumption and the accompanying dollar saving. Additional advantages include:

Electronic ballasts weigh less than conventional ballasts and are therefore easier to install.

Flicker and ‘strobing’ effects are essentially eliminated by the high frequency operation.

Lower noise levels can be expected.

Electronic ballasts run cooler and require less air conditioning.

One 4-lamp ballast can often replace two 2-lamp electromagnetic ballast.

The quality of light is usually improved.

DISADVANTAGES

The primary disadvantage to electronic ballasts is initial cost. They cost more but as the industry gears up for higher production levels, the incremental cost for electronic ballast continue to fall each year. T-8 lamps are also more expensive. It may not be economical to convert in some cases where the lighting is not used a great deal. Additional disadvantages include:

All ballasts cause some degree of harmonic distortion. A complete discussion of this subject is beyond the scope of this manual. However, it can be understood by remembering that the current in an alternating current (AC) circuit is in the form of a sine wave that repeats itself 60 times per second (60 Hertz). If there is a much smaller current (the harmonic current) that repeats itself at some multiple of 60 (120, 180, 270, 360...) times per second that is added to the sine wave, it becomes distorted. Usually harmonics are so low that there is no noticeable effect. However, they can cause malfunction of sensitive electronic equipment and, in some cases, can cause excessive current to flow in the neutral conductor of the building wiring. Electromagnetic ballasts have total harmonic distortion (THD) of around 12 to 20 %. Some electronic ballasts cause more distortion than others. Total harmonic distortion should be specified to be no greater than 20 %, and in some cases less. Harmonic distortion should not be a serious problem if ballasts are properly specified and applied. Electronic ballasts are available with as low as 5% THD. Converting to low harmonic ballasts can significantly reduce the harmonic current in a building's power system. Most modern office equipment such as copiers, computers, and fax machine, produce harmonic distortion on the power circuits, however, they may cancel each other in the circuit breaker panel, if you wish further information before using electronic ballasts contact the Energy Management Program.

Electronic ballasts produce a small amount of electromagnetic radiation (like radio waves). This is seldom a problem in an industrial or office environment There is a potential problem with such things as library magnetic detector systems and sensitive medical equipment in hospitals. In practice these problems occur very rarely.

Hazardous Wastes

Ballast replacements in an older building raises the possibility of encountering hazardous wastes. Ballasts manufactured before 1979 may contain PCBs. Any ballast not labeled "No PCBs" must be handled and disposed of assuming it does contain PCBs. Fluorescent lamps contain a small amount of mercury. In retrofits involving a large number of lamps, the lamps have to be treated as hazardous waste because of the mercury they contain. The state Department of Environment and Conservation, Division of Solid Waste Management should be contacted for specific information.

Summary

Electronic ballasts combined with T-8 lamps provide the most energy efficient fluorescent lighting available. This technology should be considered for all new lighting. Retrofits should be done where feasible.

SPECULAR REFLECTORS

Introduction

Specular reflectors are reflectors that have a mirror-like surface as opposed to a diffuse surface. They may be supplied as an integral part of a fixture or as a retrofit. They are commonly used to improve the light output of fluorescent fixtures, but could be used with other light sources as well. They have been on the market for several years and there are a number of manufacturers that provide them. The special characteristics of specular reflectors make their application different from that of most energy conservation opportunities.

POTENTIAL PROBLEMS

There are three potential problems that should be considered when applying specular reflectors:

a). Some vendors have made overly optimistic claims regarding their products. Eliminating half the lamps in a fixture, installing reflectors, and having the same light levels as before is a claim that is often used, but it is not likely to be achieved unless the fixture is inefficient, dirty and the lamps old. However, if an area has too much light, it may very well be possible to eliminate half the lamps, install reflectors and have adequate light.

b). Reflectors tend to concentrate the light under the fixture, thereby reducing the allowable spacing between fixtures. This characteristic can result in poor uniformity and dark walls.

c). There is a large difference in reflectors and the results will depend to a large extent on the specific reflector used and fixture itself.

Manufacturers recognize these potential problems and many provide custom design and application services. Custom designed reflectors should work better, but in some cases a generic “off-the-shelf” type may be all that is needed.

Quality was a concern early, but this technology has been in existence for several years. Established vendors, providing reasonable warranties should eliminate most quality concerns.

RECOMMENDATIONS

Caution and common sense should be used in interpreting results of reflector calculations. Field surveys are usually done without the benefit of reflectors to test the application. Estimates of savings are order of magnitude estimates based on assumptions and experience. A quality contractor can provide detailed measurements in a controlled “test” environment. A favorable life cycle cost calculation indicates that the application should be pursued. It is not a recommendation to purchase a large number of reflectors without further design and testing.

The following precautions will eliminate many problems:

a). Use a reputable vendor that can customize a reflector to a particular fixture. Some vendors have laboratory test data for specific luminaries and reflectors that can be used to predict results. Generic reflectors may be acceptable, but in many applications some custom design will be needed. Contracts may need to include an experience clause.

b). Test on a small scale before making a large investment. This will prevent many occupant dissatisfaction problems.

c). Pay particular attention to spacing and be sure the test area uses the same fixtures and arrangement as the application.

d). Be sure to consider lamp lumen depreciation. Initial light levels are not the same as maintained light levels.

SUMMARY

Specular reflectors present some unique application problems. They cannot be implemented as easily as many energy saving retrofits. However, they do offer a significant savings potential. When reflectors are used along with T-8 lamps, a lower wattage electronic ballast can be used. It is important that adequate design and testing be done in order to have a successful retrofit project.

HIGH INTENSITY DISCHARGE LIGHTING

INTRODUCTION

High intensity discharge (HID) lighting refers to lamps that produce light by discharging an electric arc through a tube containing gasses and metallic vapors. There are three types in common use. Mercury vapor lamps were the first HID lamps produced and have been in use for over 50 years. High pressure sodium (HPS) lighting has been in use for about 30 years and is commonly used for street lighting. Metal halide (MH) was developed about the same time as HPS and is used for outdoor and indoor lighting where color is important. High intensity discharge lamps are attractive because of their efficiency. Typically they are more suited to applications where they can be mounted fairly high to take advantage of the higher efficacy at higher wattages. However, some have been applied effectively as low as 8 to 10 feet.

MERCURY VAPOR

Mercury vapor lamps produce a blue-green light. Mercury vapor systems were once widely used for street lighting. They are now most commonly found in older installations and in inexpensive outdoor luminaires. They have 2 major disadvantages. One is the poor color (CRI 25 to 55) and the other is the low efficacy (25 to 50 lumens per watt) compared to other high intensity discharge sources. Mercury vapor lighting systems are seldom a good choice for new installations. One exception is occasionally in outdoor lighting, where the color is compatible with trees and plants.

HIGH PRESSURE SODIUM

High pressure sodium (HPS) produces a slightly yellow light. The color is most noticeable when compared to other light sources. Such systems are widely used for street lighting and indoor high bay lighting where color is not critical. High pressure sodium has the highest efficacy (40 to 140 lumens per watt) of any system in common use in this country and should be considered as the system of choice where energy efficiency is the primary concern.

Typical color rendering indexes (CRIs) for HPS fall into the following ranges :

Standard	25
Deluxe	70
White	80

However, a reduction in efficacy is a drawback to the higher CRI lamps. The color of even the standard HPS lamps is not usually a problem in most outdoor and industrial applications, but may be objectionable where it is necessary to match colors, such as in electronic and electrical equipment manufacture. It may also be objectionable for precision machine work. Even in these situations, it may be possible to use high pressure sodium for general lighting and provide task lighting for specific tasks**.**

METAL HALIDE

Metal halide lighting (MH) produces the truest color rendering (65 to 85 CRI) of any high intensity discharge lighting source and is used for those applications where it is necessary to identify or match colors. Since MH generally has an efficacy (50 to 115 lumens per watt) less than HPS, it is not the best choice unless the application requires a high

CRI. Metal halide is often used effectively in industrial applications where color is important and in some cases where precision machine work is being done. It is also used for both indoor and outdoor sports lighting and in other outdoor applications where color is important. Many people find metal halide lighting more aesthetically pleasing than either high pressure sodium or mercury vapor. Therefore its use is sometimes justified where aesthetic considerations outweigh absolute efficiency.

LOW PRESSURE SODIUM

Low pressure sodium has high efficacy (120 to 180 lumens per watt), but very low CRI (0 to 18). Objects look either gray or yellow under low pressure sodium light. Due to extremely poor color rendering, it has only a few very specialized applications. It can be used with black and white surveillance cameras, for example.

There is no one best light source for all applications. Energy retrofits could consist of replacing incandescent or fluorescent lighting with high intensity discharge lighting or replacing a mercury vapor system with one of the more efficient types. In general high pressure sodium is the preferred source where efficiency is the main concern. Metal halide should be considered in cases where color and aesthetics are important. Mercury vapor should be considered for conversion to high pressure sodium in situations where lighting is used a significant amount of time. Generally, the efficacy of high intensity discharge sources is higher in the higher wattages. This fact makes it desirable to use the fewest number of luminaires with the highest wattage practicable. Since the space to mounting height ratio cannot be too high without causing light and dark spots, lower wattages are required for low mounting heights. In many cases the efficacy of a well designed fluorescent system is comparable to that of a well designed high intensity discharge system where ceiling heights are in the 10 foot range.

DAYLIGHTING CONTROLS

The advantages of using natural daylight were discussed in the Section 4.1.3.2, as low cost energy conservation opportunities. For areas that require fairly constant light levels, it is possible to install a system using dimming fluorescent luminaires to adjust for varying levels of daylight. There are several systems of dimming fluorescent ballasts on the market. One of the easiest to apply uses a dimming electronic ballast along with a photosensor for each luminaire. The sensor is mounted on the ceiling near the luminaire it controls. By making field adjustments, it is possible to control the light level and achieve a high degree of uniformity throughout the space and a consistent light level with varying daylight conditions.

Such a system is advantageous for an office area, because significant changes in light levels are disruptive and annoying to office workers. A simpler, less costly system should be used in areas not needing a constant light level.

There are two significant disadvantages to using daylighting controls. First, the efficacy of a dimming system is less than a standard system. That is, a dimming electronic ballast requires more wattage at full light output than a standard electronic ballast. Second, the cost usually makes a fairly long payback. Although daylighting is a good idea, it is seldom among the most economically attractive retrofit options. The incremental cost of installing a daylighting system instead of a conventionally controlled system initially is much less than the cost of retrofitting later. This makes the economic benefits greater if it is done when the building is being built or when the lighting is being upgraded.

Estimating the potential savings with daylighting is fairly simple. By assuming a saving of 50% in daytime lighting required it is possible to determine an order of magnitude of the possible savings. Cost can be readily estimated using vendor price lists along with labor estimates. At this point it is usually obvious if there is the possibility of adequate savings to justify the ECO. The following example will illustrate the calculation.

Assume:

Lighting in the area where daylighting can be utilized, consists of 100 fluorescent, 4 lamp luminaires, requiring 120 watts each (typical for a T-8 /electronic ballast system) Lighting is used 10 hours/day, 5 days/week (about 2600 hours per year)

The cost of installing dimming ballasts and controls (including labor) is about $50 per luminaire

The cost of electricity is $0.07 / kilowatt-hour

(Numerical values are for illustration only. Use appropriate data for the particular application)

Estimated Annual Saving =

(1/2)(100X120/ 1000)(2600)($0.07) = $1,092

Estimated cost = $50 X 100 = $5,000

Simple Payback = $5,000 / $1092 = 4.6 years

At this point it is apparent that the retrofit may be cost effective. Had the simple payback been 20 years it would be apparent that the retrofit would not likely be economical. The calculation in the example is an estimate of the order of magnitude only. Such a calculation is useful to eliminate projects that clearly do not have an economic potential. It is necessary to do more precise calculations to determine the actual savings. The Energy Management Program should be consulted for the final evaluation. There are several hand calculation methods to estimate the savings due to daylight contribution, but because of the complexity, it is usually preferable to use a computer simulation such as DOE-2. The computer simulation also has the advantage of accounting for changes in heating and air conditioning loads.

MOTORS

Electric motors can be a significant user of electricity in a building. Typically motors are considered to be very efficient and often little consideration is given to improving efficiency. Motors can be divided into alternating current (AC) and direct current (DC).

Direct current motors are often used in such things as elevator drives. Typically an AC motor is used to drive a DC generator that in turn powers a DC motor. This arrangement, known as a Ward-Leonard system, facilitates motor speed and torque control. While solid-state controls are now available to perform this function, there are many of the motor-generator sets still in use.

Alternating current motors are either single phase or three phase. Single phase motors are usually small or fractional horsepower and have little effect on the building energy consumption. Three phase motors make up the largest part of the motors in a typical commercial building. Furthermore squirrel cage induction motors are the most common. Since they are by far the most common type encountered, the following discussion will concentrate on three phase squirrel cage induction motors.

Over the past several years most manufacturers have developed premium efficiency motors. It is possible to build more efficient motors by using better materials, more copper in the windings, bearings with less friction, etc. Most manufacturers currently build premium efficiency motors. It is often economical to install energy efficient motors or replace existing motors.

Historically the biggest drawback to induction motors has been speed control. The only way to change speed is to change either the number of poles or the frequency. Two speed motors that allow changing the number of poles by reconnecting the stator windings are common. As a practical matter, the number of available speeds that can be achieved by changing poles is severely limited. The development of efficient, reliable solid state controls has allowed the variation of the frequency to become a means of controlling the speed of large AC motors.

LOW COST ECOs

a) The primary low cost ECO is proper maintenance of motors and motor driven equipment. Worn bearings, belts that are over-tightened, mis-aligned equipment, and equipment that is not operating properly requires more motor power.

b) Installing energy efficient motors in place of failed standard motors in applications where the motor runs a significant amount of time is usually a good idea. In some process , such as fans and pumps, the power input can increase if the speed of the energy efficient motor is greater than that of the original motor, contact Energy Management Program for assistance.

CAPITAL ECOs

PROPER SIZED MOTORS

Motors are usually efficient machines, having efficiencies on the order of 90 percent or higher, depending on the size and type. However, efficiency drops drastically when the load decreases to somewhere between 25 and 60 percent of full load. Motors are frequently found to be oversized for a variety of reasons. They may have been sized too conservatively. The load may not be as large as anticipated. The load may have changed. A larger horsepower replacement motor may have been installed, because the proper size was not available. It is simple to, roughly, estimate the motor load by measuring the current. It is important to be sure that the load measured is actually the maximum load for the application. For example, if a fan motor current is measured with inlet or outlet vanes closed, a deceptively low reading will be obtained. An additional consideration that must not be overlooked is the fact that a motor that is lightly loaded is not using very much energy, although the efficiency is low. If a motor is grossly oversized, it may be economical to replace it with a properly sized motor.

ENERGY EFFICIENT MOTORS

Substantial savings can be achieved by replacing standard motors with energy efficient ones. The savings and payback are a function of the size and hours of operation. Generally motors over one horsepower, that run at least 2600 hours per year should be considered for replacement. It is important to consider the actual efficiency, if possible, because efficiencies vary considerably between manufacturers. An energy efficient motor may have a slightly higher speed than a corresponding standard motor. In that case, care must be taken with loads such as pumps and fans, because the power required varies with the cube of the speed. For instance, if the energy efficient motor is 2% faster than the motor it is replacing, it will supply 8% more power to the load. In such a case the actual energy used may go up. Of course it may be possible to change a pulley to slow the fan down to its normal speed. In many cases the efficiency of a motor decreases after it is rewound. For that reason it is usually more economical to replace failed motors with energy efficient motors instead of rewinding them.

ADJUSTABLE SPEED DRIVES (ASD)

The adjustable speed drive (also called variable frequency drive or variable speed drive) is simply a means of changing the speed at which a motor operates. In the case of an AC motor this is accomplished by changing the frequency of the voltage applied to the motor. Since the motor speed is proportional to the frequency, this changes the speed. Applying adjustable speed drives to fans and pumps can be particularly effective, since the power required is proportional to the cube of the speed. Direct current (DC) motors have historically been used in situations where adjustable speeds were required. The development of solid state AC adjustable speed drives has made it possible to control the speed of AC motors easily. There are many applications where AC motors are being used with mechanical means of controlling the output. For example, there are motor systems that use variable pitch v-belts. Eddy current drives are a means of introducing a variable slip between the motor and the driven equipment. Many motor systems operate at full speed only during peak weather condition. The most common situation is in the case of fans and pumps where the air or fluid flow is controlled by throttling (such as by closing the inlet vanes on an air handling unit). This does reduce the power required, but the relationship between flow and power input is approximately linear. By reducing the speed of the fan, the power input becomes proportional to the cube of the speed. For example reducing the speed of an air handling unit motor by half, reduces the power required to approximately 1/8 of full load. Since this may occur for more than ½ of the operating hours per year the saving can be very significant. Adjustable speed drives can cause such problems as motor heating and bearing damage and power quality problems. Also, the distance between the drive and the motor is limited. For that reason, it is important that they be properly applied. Contact the Energy Management Program for specific applications.

MISCELLANEOUS

The power system itself uses little energy. Transformers are usually quite efficient. Any new or replacement transformers should be specified energy efficient. Added harmonic currents from modern office equipment may require larger transformers that are de-rated. Consult your local utility to ask for help in analyzing your loads.

LOW COST ECOS

a). Reduce energy consumption by turning off unneeded loads.

b). Manage the loads so as to reduce peak demand. There are several ways to do this. For instance, if there are a few large, infrequently used loads, it may be possible to only run one or two at a time and control them manually. Time clocks may also be a low cost option. Be sure large motors do not all start within the same 15 minute period if there is a chance of setting a higher than normal peak demand.

CAPITAL ECOS

a). Power factor correction can save significant amounts of money. This is not strictly an energy saving, because it is a reduction of apparent power instead of real power. Power factor correction is done by adding capacitors to the system. The design should be done by an engineer.

b). Peak shifting is a technique of using the same energy, but reducing peak loads by changing the operating schedule of equipment. This can be done manually, with time clocks or with an energy management system.

c). A discussion of energy conservation would not be complete without mentioning the subject of submetering. Often an entire complex is supplied through one meter. This may be good for the utility because only one meter has to be read and maintained. It also has advantages for the state because the rate may be more favorable and it tends to level out peak demand. However, it is difficult to manage energy if you cannot tell where it is going. Often just making people aware of their energy use will encourage them to conserve. Sub-metering can be added at panels and need not be used by the utility for determining electric charges.

HEATING VENTILATION AND AIR CONDITIONING (HVAC)

GENERAL CONCEPTS

The building heating, ventilating, and air-conditioning (HVAC) system is the largest single user of energy in most buildings and often contributes to over half of an office building annual energy consumption. This is the major area where energy conservation measures may be identified and have potential for a payback in reasonably short time.

Energy saving for the HVAC system may be separated, based on the cost of implementation and categorized into three areas; maintenance ECOs, low cost ECOs, or capital investment ECOs. The maintenance and low cost ECOs can be implemented easily by building maintenance personnel. Capital investment ECOs generally need a Professional Engineer to perform more detailed analysis and cost benefit evaluation.

The three areas of saving are:

a). Reduction of load and time of operation

b). Improving equipment efficiency.

c). Reduction of friction loss of air movement; reduction of pump head loss in piping; reduction of heat loss or heat gain in duct and piping.

REDUCTION OF LOAD AND TIME OF OPERATION

HVAC system energy consumption equal: hours of operation multiplied by the cooling or heating load. In order to reduce the energy consumption, the following measures may be considered:

<u>Schedule start/stop</u>: Turn off all cooling equipment. and operate heating equipment only to maintain the minimum temperature of 50°F in the winter when building is not occupied and IAQ is not a concern.

<u>Optimum start/stop</u>: This saving is derived from minimizing the necessary warm-up or cool-down time prior to occupancy and by shutting down the system as early as possible before the end of the occupancy period. The optimum time will vary from building to building and weather conditions. It depends heavily on experiences of the building manager, normally, the time can be from 1 to 3 hours. In stead of installing an expensive Energy Management Control Systems (EMCS), programmable thermostats for small buildings can now perform these functions.

<u>Temperature resets</u>: HVAC cooling/heating load can be reduced by lowering or raising the thermostat settings. It is recommended that the

thermostats be reset during unoccupied periods. The office temperature recommended for the summer is 75°F, and 72°F for winter. Dehumidification in the summer shall not be lower than 60% and humidification in winter shall not be higher than 30%.

Shut down unused room or zone: Conference room and auditoriums are not always occupied. HVAC systems serving these areas should be able to be isolated and shutdown, when not in use. Heaters in the entry airlocks, should be disconnected or removed.

Prevent simultaneously operating heating and cooling equipment: Dual-duct terminal reheat or hot deck/cold deck multizone systems should be converted to variable air volume (VAV), in order to prevent operating boiler and chiller simultaneously.

Economizer cycle: Use outside air for cooling to prevent the compressor from running during mild weather. This measure has potential savings for the 24-hour operation building; otherwise a more detailed analysis based on the weather conditions in the area and cost of modifications is needed.

Recover the reusable energy: Computer room heat usually can be recovered and used to heat other areas. Laboratory exhaust air can be recovered by an air to air heat exchanger to pre-cool or preheat the outside air intake. Laundry and kitchen areas can use the recovered heat for hot water preheating. The IAQ problem must be considered if the exhaust air is to be recycled for energy recovery. Generally, if the building is dumping excess energy at about 300 KW, through the cooling tower, condenser, or exhaust air; heat recovery can be obtained by the use of a heat recovery chiller, double bundle chiller or heat pump chiller.

Outside air intake control: The ventilation air intake should be reduced to the minimum as recommended in the ASHRAE 62 standard (latest issue at the writing is 1989 with 1990 addendum). For the general office 15 to 20 CFM per person is adequate, any excess outside air intake should be stopped. The heat pipe or heat recovery wheel can be used to recover the exhaust air energy. Use of modern equipment to clean recycled air to acceptable standards can greatly reduce the cost of heating/cooling outside air required. Ask for more information from the Energy Management Program. The kitchen hood exhaust should have an independent makeup air supply to reduce the cooling/heating load. Desiccant wheels or heat pump should be considered if a tight humidity control is required.

Water source heat pump: Water source heat pumps eliminate the water chiller and circulate warm temperature water in the system , reducing the pipe energy loss. Also it can simultaneously operate in heating and cooling mode for different zones by exchanging energy between two zones. If the building has a large window area in east or west, an energy exchange between the perimeter and internal core area is possible, and the total cooling or heating load can be reduced considerably.

Radiant heater: The temperature differential in a high ceiling area could reach 7° F per 10 ft in height. To avoid heating the high ceiling area of a garage or storage area, the heating system should be replaced with radiant heaters. The radiant heaters are best for: (a) high ceiling area, (b) areas in which doors are frequently opened and closed. The same comfort level can be achieved by lowering temperature settings and using radiant heaters.

IMPROVE EQUIPMENT EFFICIENCY

The equipment efficiency is inherent when equipment is purchased, but good maintenance and operation will keep the efficiency from decreasing during the equipment life time operation. Several measures, as shown below, can be implemented:

Maintenance manual: Listing the building equipment which consumes energy, is the first step for energy management. The preventive maintenance for each equipment should be scheduled and a vendor's manual should be in place for easy reference and record keeping. Labeling equipment to match ID on the schematic drawings will help maintenance personnel in identifying the equipment.

Chiller: The chiller efficiency is expressed as COP (Coefficient of Performance). The chiller, when purchased, should have its COP shown in the user manual. The COP normally ranges from 2.8 to 4 or better. The COP can be calculated by measuring the power input to the compressor and comparing with the chilled water entering and leaving water temperature. The formula is:

COP = heat removed / power input

$$= \frac{500 \times GPM \times (EnteringWaterTemp - LeavingWaterTemp)}{PowerInput \times 3.41}$$

(Reference 9.2, Page 1.4)

Compare the existing COP with the original COP to find out the deterioration of the equipment. There are several ways to increase the COP of the chiller:

a) Raise the chilled water leaving temperature, if it is acceptable

b) Clean the condenser and evaporator heat exchangers to lower the fouling factor

c) Avoid chiller partial loading by operating a smaller chiller, if available, or one chiller in a multiple chiller building

d) Hot gas by-pass control for the chiller should be discouraged. Adjustable speed chillers are becoming more popular for controlling the partial load

Electric hot water boiler: There is not much saving that can be achieved unless drum insulation can be added. Generally, adding insulation to an existing insulation will not have an acceptable payback.

Natural gas fired hot-water-supply boiler: Proper adjustment of the burners and maintenance of boilers and furnace will improve the combustion efficiency and reduce fuel cost. A boiler larger than 100 HP should have a log book to record the boiler load so that a decline in the combustion efficiency can be easily detected.

Steam boiler: If the boiler is larger than 30,000 BTU, an automatic blowdown device may save cost. All condensate should return to the feedwater system and minimize the loss. The combustion fuel/air ratio should be monitored and adjusted if necessary.

Steam Trap: Annual inspections using an infrared scanner during high load periods should be performed to ensure steam is not leaking through unseated traps. Normally, steam trap orifices should be replaced with new ones between 2 and 3 years.

Supply and return air fan: The fan bearings should be lubricated as scheduled. Centrifugal fan blades should be inspected at least annually and cleaned. An ASD (adjustable speed drive) should be considered if the fan motor is larger than 7 ½HP and the load is varied considerably during the hours of operation.

Water Pump: The shaft seal should be periodically inspected and proper adjustment made to minimize water leakage. An ASD installed on the pump motor can be utilized if the load falls off considerably during hours of operation.

Heat exchanger: The shell and tube heat exchanger should be cleaned when the heat transfer effectiveness declines more than 5% from the original value. The heat transfer effectiveness is defined as:

Effectiveness = (TLE - TLL)/ (THE- TLL)

(ref. 9.10 page 181)

Where:

TLE = shell side entering temperature
TLL = shell side leaving temperature
THE = tube side entering temperature.

Air cooled condenser: Condenser should be inspected annually for fin damage or any blockage of the air passage. The condenser ineffectiveness can be detected by high side pressure deviation from the original specification. The refrigeration compressor COP will improve if the condenser is effective.

Cooling Tower: If the cooling tower fan is larger than 10 HP, an ASD for the fan motor may be considered. Condensing water treatment should be adequate. New chemicals are available to clean the inside of the cooling tower effectively. Some treatments can also reduce fouling in existing heat exchangers. Cooling tower efficiency affects chiller COP significantly but sometimes it is difficult to justify the cost of replacement for energy saving purposes alone. Inspection by a competent professional should be considered when in doubt.

REDUCTION OF FRICTION LOSS FOR AIR MOVEMENT OR HEAD LOSS OF PUMPING

Reduce the heat loss from pipe and duct: Pipe insulation is the most effective way to reduce losses in the hot water system. In most cases, it is difficult to justify adding insulation to existing insulation. However, damaged insulation should be repaired. Ducts penetrating the unconditioned area should be insulated. If a ceiling space is used for the return air plenum, the wall above the ceiling space should be insulated, as well as the roof, if possible.

Duct leakage: The rectangular duct with lock-seam joints sometimes will have excessive leakage when a fan system is upgraded. Leaks can be detected by sounds or feeling. The leak should be sealed to minimize the fan power required.

Variable air volume (VAV) and Adjustable speed drive (ASD) control for the AHU: The fan horsepower consumption is proportional to the RPM cubed. Therefore, If the fan can be slowed to 80 % of full speed, the power consumption is $(0.8)^3$ of full speed power consumption or about 50 %. The payback period will depend on the size of motor and fluctuation of load during operation.

Primary-Secondary pumping system for the chilled or hot water system: The conversion to the primary secondary pumping system with an adjustable speed pumping system is generally recommended if the pump is larger than 15 HP, daily operating time is more than 10 hours and load fluctuates considerably.

Clean Air Filter: The fan power consumption is proportional to the air flow and system friction. The filter friction sometimes contributes a significant portion of the fan power required. Clean filters will save energy.

<u>Remove scale from water and steam pipe</u>: Scale buildup in water and steam pipes increases flow resistance and reduces heat transfer in coils. This condition usually can be detected by the increase in pump power consumption versus GPM. Consult with a qualified professional for recommendation.

<u>Reduction of main pump head</u>: A dedicated booster pump should be considered if a separated but long-run loop is in the system.

CFC CONCERNS IN THE REFRIGERATION SYSTEM

The most serious concern in the HVAC field to-day is the use of ozone-depleting CFC refrigerants. In considering improving the chiller efficiency, this problem cannot be ignored. There are several new refrigerants being developed and are already being used to replace the CFCs. The chillers using R-11 and R-12 in a building should be replaced with more efficient chillers that use HCFC-123 or HFC-134a as the refrigerant. A heat pump using HCFC-22 may be used until the year 2010.

The options for replacing existing CFC chillers are listed but not limited to follows. Advance in chiller technology may increase the number of options. The life cycle cost for each option should be calculated and used as a basis to select the best option.

a). Replace existing chillers with higher COP, CFC free chillers.

b). Convert R-11 centrifugal chiller to HCFC-123 chiller.

c). Convert R-12 centrifugal chiller to HFC-134a chiller.

d). Replace reciprocating chiller with higher COP scroll chiller.

e). Convert chilled water system to water source heat pump system and abandon the chiller.

f). Replace compression chiller with freon-free brine absorption chiller.

g). Utilize thermal storage flywheel effect and reduce the size of chillers.

SUMMARY

The above mentioned energy conservation measures can be implemented if the payback is within 10 years. Energy Monitoring and Control Systems (EMCS) have become more cost effective in recent years because of decreases in the hardware cost. Generally, if buildings

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have chillers above 100 tons and have more than 4 or 5 AHUs and 2 pumps, it is worthwhile to investigate the installation of EMCS with DDC controls.

ENERGY MONITORING AND CONTROL SYSTEMS (EMS)

Energy Monitoring and Control Systems (EMCS) offer a number of benefits. Since they are microprocessor-based systems, they are programmable and have a very high degree of flexibility and accuracy. Many energy saving strategies can be achieved through programming the EMCS.

Advancements in computer technology have made EMCS available at a price that is cost effective in many existing buildings. Today's EMCS are almost all based on a personal computer with local "smart" direct digital control (DDC) panels that can operate in a stand-alone mode. They range from fairly simple to very complex, containing thousands of sensors and operators. Often systems are connected together to allow control of a building from a remote location.

If a building is larger than 40,000 square feet and has chillers, boilers and AHUs, or fans, that need to be coordinated and monitored for the best performance, an EMCS should be a feasible solution. The cost-effectiveness of such a move will be determined by how well existing manual and automatic controls operate the building systems. Older technology can be used to perform most of the functions of an EMCS. If existing controls are operating effectively and are reliable, the savings from installing an EMCS may not be enough to justify the cost.

Monitoring functions will not directly contribute to energy saving, but will help maintenance personnel to pinpoint problems prior to occurrence and save maintenance costs. Monitoring also helps show where energy is being used and may suggest operational changes that will reduce consumption.

The following monitoring and control features are recommended but not limited to :

b) Read and retain daily totals of all energy measurement instruments
c) Total all energy values weekly and retain values on a summary report).
d) Record and plot hourly outdoor and indoor temperatures against real time
e) Perform time based on-off control of HVAC equipment
f) Perform time based on-off control of lighting
g) Reset local loop control systems for HVAC equipment

h) Monitor and control heating, cooling and energy delivery systems to ensure no overlap of heating and cooling exists

i) Monitor and control lighting and power, auxiliary and service hot water systems

j) Provide readily accessible override controls for HVAC and lighting.

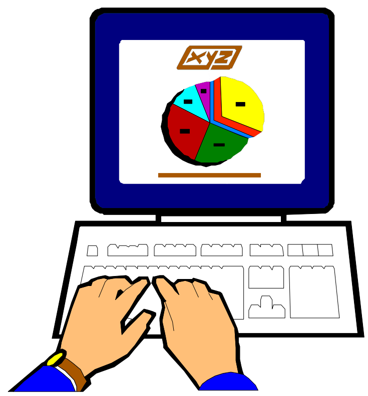
k) Provide optimum start/stop for HVAC

l) Electrical demand limiting

m) Remote monitoring

n) Coordinate outside air intake control with carbon dioxide (CO_2) sensors to keep room air at 1,000 PPM or less

o) Monitor speed of adjustable speed drive (ASD) application to ensure proper operation as building load changes



The more automated "controls" of the HVAC systems and equipment that is provided by the EMCS, the more significant will be the energy saving and occupant comfort. However, more control also means higher initial cost. It is therefore very important to achieve the right balance of control and monitoring in the design of an EMCS. A qualified engineer or system vendor should be used whenever a system is installed or upgraded.

The installation of an EMCS is a capital investment. However, in many cases existing systems are found to be used at less than their full capacity. It may be fairly simple and inexpensive to add controls and improve the effectiveness of existing systems.

SERVICE WATER SYSTEM

DOMESTIC HOT WATER

Heating water consumes about 4% of the total energy used in most large state-owned buildings. In smaller office and classroom buildings, this percentage is somewhat lower. Buildings with cafeterias and/or laundries will use a higher percentage of total energy.

Domestic hot water may be heated by the same boiler that provides heat for the building or by a separate water heater. If the heating boiler provides the hot water, the domestic hot water load on the boiler may be 10 to 20% of the total boiler load in the winter heating season. During the summer, when the boiler operates at low levels just to produce domestic hot water, this percentage will be much higher due to the inefficiency of a boiler which short-cycles under the light load.

There are several opportunities to conserve energy used in producing domestic hot water. These include:

a) Reducing the quantity of domestic hot water used by educating and encouraging the occupants to conserve water

b) Lowering the supply temperature of the domestic hot water

c) Repairing all leaks promptly

d) Insulating the piping and storage tanks

e) Reducing recirculating pump operating time

f) Increasing the efficiency of the domestic hot water generator by ensuring the equipment is maintained and operating properly.

g) use low flow showerhead and low flow faucets

AVERAGE USAGE OF DOMESTIC HOT WATER

Facility	Function	Gallons / day / person
Office Buildings *	without kitchens or cafeterias	2 - 3 gallons
Schools *	Daytime only	3 gallons
`	Boarding	25 gallons
Hospitals	Medical Centers	30 gallons
	Mental	25 gallons

** with kitchens or cafeterias add 3 gallons per meal served plus 3 gallons per kitchen employee.*

METHODS OF GENERATING AND STORING DOMESTIC HOT WATER

There are several ways of generating and storing domestic hot water. Some of these are:

a) Tankless heater included in a hot water or a steam boiler used for heating the building

b) Heat exchanger/storage tank combination which is connected to a hot water or steam-heating boiler by piping

c) Separate oil, gas, coal, or electric domestic water heater with an integral storage tank

d) Separate oil, gas, steam, or electric booster heaters with storage tanks

e) Instantaneous hot water produced by heat exchangers using either steam, hot water, or gas as the heating medium

f) Heat pump hot water heater

NOTE: This system provides cooling as well as the hot water. Depending on the building hot water requirements, this system may not provide all of the hot water needed.

g) Solar collectors mounted on the roof or on the ground and connected to a storage tank

NOTE: This system can meet most of the domestic hot water requirements in many locations.

h) De-superheater water heater.

NOTE: This system uses a heat exchanger added in the refrigerant hot gas line between the compressor and the condenser. A double wall heat exchanger shall be used to vent the refrigerant in case of leak between water and refrigerant. Every refrigeration or air conditioning system has available heat energy which can be recovered.

i) Heat exchanger added in the condenser cooling water line between the chiller condenser and the cooling tower

NOTE: This system can preheat the domestic water before being raised to the supply temperature by the hot water heater. Condensing water can also serve as a heat source for a water source heat pump. These systems will preheat water and reduce the load on the cooling tower.

j) Tankless under-counter electric instantaneous water heaters

NOTE: These water heaters can be mounted on the wall below the lavatory. These “point-of-use” water heaters save energy by heating water only when needed. Only one cold water line needs to be connected to the lavatory. This “point-of-use” water heater eliminates the heat loss from long hot water supply lines.

WATER TEMPERATURES

The usual temperature set point for hot water is between 120° F and 150° F. This is much too hot to be used directly and must be mixed with cold water at the faucet to prevent injuries. The temperature required for dishwashing is 140° F and higher and the temperature for dish/utensil sterilization is 180° F or higher. When all the hot water supplied in the building is this hot, it becomes quite wasteful. Besides, many dishwashers heat their own water. When hot water is supplied by a tankless heater from the boiler system, it is delivered at a temperature within 5° F or 6° F of the water temperature delivered by the boiler to heat the building. Even with a mixing valve, the domestic hot water temperature frequently remains higher than required. The resulting energy losses are considerable.

The health concern of Legionella must be considered when setting the hot water supply temperature. The maintenance programs for all water systems (regardless of whether or not any evidence of Legionella is suspected or has been detected) must be carefully reviewed. It is essential that all areas in potable water systems in which water may stagnate be identified (e.g., laterals which have been capped off or storage tanks which may have “dead zones”). It is also important to identify and test the integrity of all backflow preventers. Routine maintenance of hot water systems should include at least an annual cleaning to eliminate scale and deposits in the hot

water system and tanks. Assure that all natural rubber gaskets have been replaced with Teflon or other material not conducive to bacterial growth.

Given the right set of environmental conditions, Legionella has been shown to propagate at temperatures between 20^{o}C and 50 ^{o}C (68 ^{o}F and 122 ^{o}F). This range puts both the cold and hot water systems at risk. Therefore, the potable cold water temperature should be maintained below 20 ^{o}C (58 ^{o}F) and the chlorine levels should be ideally in the range of 1 to 2 ppm. The amount of chlorine in municipal water will dissipate with time and may reach a very low concentration by the time it reaches a facility from a distant treatment plant. Cold water storage tanks, therefore, are not advisable. If used, the tank should be designed for a maximum of one day's water requirements.

Potable hot water systems are designed to provide heated water for cooking, washing, cleaning, consumption, etc. Multiple independent systems may be present in a large building. These systems typically consist of a boiler or heater, a distribution system, and pipes terminating in faucets and equipment. Operating temperatures may vary depending upon system design, energy conservation programs, and intended use of the hot water. If the potable water system has been checked for proper design and the absence of Legionella has been verified, then no measures need be implemented at this time. The hot water system, should Legionella ever be found present, must be cleaned, pasteurized, stored at 60 ^{o}C (140 ^{o}F), and delivered from the faucet at a minimum of 50 ^{o}C (122 ^{o}F). When test samples no longer indicate the presence of Legionella, the system may be returned to normal operational status.

DISTRIBUTION

Hot water is distributed by either the system water pressure (gravity) circulation or by a recirculating hot water pump. The water pressure or gravity-type circulation system wastes water by making it necessary to run "cooled-off" hot water out of the piping before the hot water comes out.

Systems using a recirculating hot water pump deliver hot water almost instantly at the faucets. This decreases the total amount of water used, since the lengths of pipe filled with "cooled-off" water are relatively short. However, using a recirculating pump may be wasteful where all of the faucets are located near the hot water tank. It is important to realize a recirculating pump increases heat loss through the pipe insulation since the entire hot hater piping is maintained at the tank temperature. For piping systems that require the pump to operate at all times, adding an ASD drive may be appropriate to maintain the pressure without wasting pumping energy

REDUCING THE QUANTITY OF HOT WATER USED

Low flow shower heads and faucets for the building can be installed for reasonable cost.

There are several benefits from reducing the quantity of hot water used.

The three listed are a reduction in:

a) Energy consumed for heating water
b) Water consumption charges (and often sewer charges as well)
c) Sewage treatment required in treatment plants belonging to the local utility district or the State of Tennessee.

GENERATE HOT WATER MORE EFFICIENTLY

All of the measures listed for improving units for space heating discussed earlier apply equally as well to water heaters. Keep in mind, however, that when more than one heater is installed, it is more efficient to operate one for the total load, if it can carry it, rather than to operate all water heating devices at partial loads.

WATER CONSERVATION

GENERAL CONCEPTS

Water usage can be categorized as follows:

a) Potable water for drinking, making ice, making coffee, etc.
b) Potable water for the rest rooms (hand washing, flushing, showers, etc.)
c) Potable water for janitorial use (cleaning, scrubbing floors, etc.)
d) Potable water for boiler feedwater makeup
e) Potable water for cooling tower makeup
f) Potable water for once-through condenser cooling
g) Potable water for watering grass, trees and shrubs
h) Potable water for outside decorative water spray fountains, etc.
i) Potable water for cooking, preparing food, and washing dishes, (if applicable)

Water management techniques include three general areas:

a) Reducing losses (for example, fixing leaky faucets and pipes)

b) Reducing the overall amount of water used (for example, using low water volume flush toilets and automatic shut-off faucets)

c) Reusing water that would otherwise be discarded (for example, treating water from sinks and cooling tower filter backwashes for use on landscaped areas)

Water conservation opportunities in buildings usually are low cost or no cost measures. True and total cost of water is not just the amount on the water bill, but also includes the cost to heat, treat, and pump it to where it is needed. It also includes sewage treatment costs.

An effective plan is one that fully outlines not just how much water is used, but how it is used and by whom.

The following water conservation measures can be implemented easily:

a) Educate the occupants to conserve water and report promptly any leaks.

b) Set up a "hot line" that encourages and rewards occupants to call and report any problem they find.

METERING

a) Monitor and record the water usage on a monthly basis. Compare the results with the bills from the utility. Analyze the results and make operational changes as necessary.

b) Make a list of all the equipment that uses water and determine the approximate volume of water required.

c) Monitor the boiler makeup water and cooling tower makeup water on a regular basis. Analyze the results and make operational changes as necessary. Have water utility company subtract from wastewater treatment charge.

d) Water management should address both the supply side and the demand side. In other words, do not just focus on building occupants; also work with your water utility.

STOP LEAKS AND WASTE

Promptly repair any leaks or dripping faucets.

INSTALL FLOW RESTRICTING DEVICES

a) Install flow restricting devices to limit the flow to 0.5 gpm at all lavatory faucets not covered by the Americans with Disabilities Act. The cost is low and can easily be installed by maintenance personnel in 5 to 10 minutes. For faucets that already have threaded, anti-splash, and aerated flow adapters, installation of new flow restricting devices is easy. For faucets without threads, a threaded insert can be installed to accept the flow restricting device.

b) If applicable, install flow restricting devices to limit the maximum discharge to 2.75 gpm at all shower heads not required for safety reasons. The cost is generally low and can easily be installed by maintenance personnel.

AUTOMATIC FLUSH VALVES

Install battery-powered, automatically operated, retrofit adapters for flush valves to improve hygiene, reduce maintenance costs, conserve water, and meet ADA requirements. These can be installed by maintenance personnel in 20 to 30 minutes. The battery-operated retrofit adapter senses the presence of the user and automatically flushes as the user moves away. The user does not have to touch the flush mechanism.

For example: A typical urinal uses 1.5 gallons per flush. An automatic flush valve can reduce this to 1.0 gallon per flush - a saving of 0.5 gallon per flush.

EXTERIOR DECORATIVE WATER-SPRAY FOUNTAINS

Consider decommissioning outside decorative spray fountains. This will not only save water but will eliminate the electricity cost for pumping the water. The fountain catch basins can be landscaped with plants and shrubs that require minimal watering. Or the catch basins can be landscaped as rock gardens.

NEW TOILETS

Consider replacing the existing toilets that use 3 to 5 gallons of water per flush with new toilets that use only 1.6 gallons per flush. This is especially true when remodeling or replacing a broken toilet.

GOALS

The goal is to reduce the water usage by 10 to 30%.

Conserving water within a building also affects other building systems. For example, reducing the amount of hot water used in a dishwasher would also reduce the amount of electricity needed to heat that water. This adds to the energy conservation of the facility.

Implementation should be done in phases, starting with the obvious no-cost options.

Building management must be committed to water management to convince occupants that their actions make a positive difference.

SUMMARY

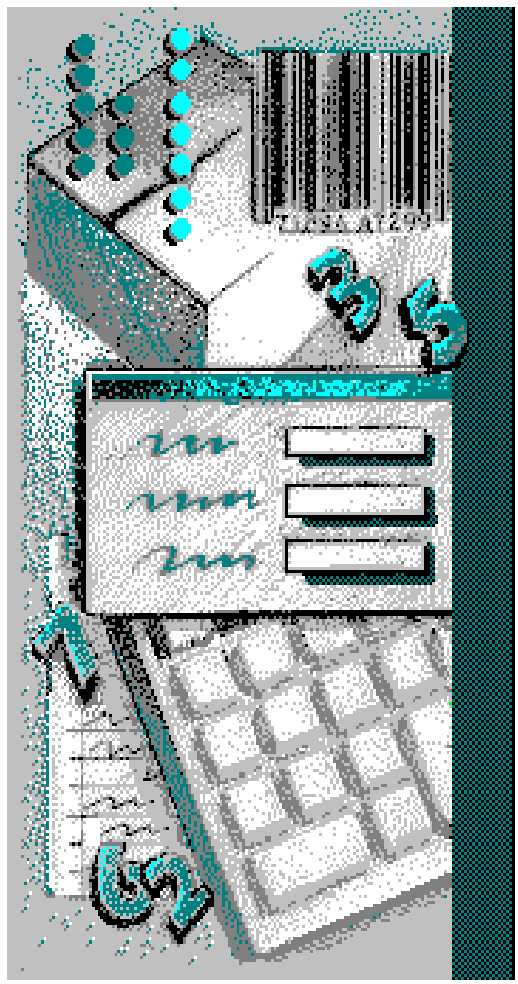
Domestic hot water is a relatively small energy user in most state buildings. However, long term energy savings can be realized in this area by applying the ECOs listed in Appendix B.

MISCELLANEOUS SYSTEMS

Every building has equipment and energy using components which vary in kind and importance, depending on the specific function and construction of the building. Individually these functions may be as significant as a laundry facility in a hospital or as minor as a coffee pot in an office.

Regardless of the energy used by any single piece of equipment, the total used by all miscellaneous equipment is usually quite substantial. Much of the information needed to compute the energy consumption will be found on the nameplate of the equipment. This chapter covers items which have not been previously mentioned.

COMPUTER FACILITIES



In buildings that have a substantial main frame computer installation, significantly more energy is used than in a comparable size building without mainframe computers. The computer equipment itself is partly responsible, but a large amount of energy is used to remove the heat generated and to support the operations. Typically computer operations extend beyond normal operating hours. There are steps that can be taken to at least insure that no more energy than necessary is used to support computer operations. The logical first step is proper zoning of HVAC and lighting systems to isolate the areas. The excess heat generated by the computers may be used to heat other parts of the building in the winter. Recent experience has shown that computers are becoming smaller and more efficient, When computers are replaced, the new ones often do more for less energy and take up less space. It is not uncommon to see main frame computer areas being converted to general office space. When this happens, the HVAC system is probably oversized and will be inefficient. Upgrading the HVAC system to match the new load may be recommended in such cases.

PERSONAL COMPUTERS (PC's)

The most significant change in today's office from that of fifteen years ago is the widespread use of personal computers. A typical computer uses on the order of 100 watts when it is operating. Individually, this is not much, but in densely staffed office areas, with computers on every desk, the computer load can be almost as large as the lighting load. Therefore it is important to practice energy conservation with computers or utilize DPMS(Device Power Management System) program. They should be turned off when not in use, and energy efficient computers should be specified for new purchases. Occupancy sensors are available to automatically turn off the monitor and printer when an area is not occupied. Devices are also available to turn off the monitor and printer when the computer has not been used for a specified period of time.

ELEVATORS AND ESCALATORS

Despite the fact that escalators draw little current under no-load operation, it is generally recognized that their continuous operation does tend to waste energy. Although intermittent as-needed operation can be obtained through the use of a treadle-type switch, relatively few such installations have been made due to safety concerns. When an escalator is shut down it still provides a means of transportation: stationary stairs. Thus time clocks should be installed on all escalator systems. When elevators are running they tend to be more efficient than escalators, even though they cause indirect energy consumption due to infiltration in the elevator shaft and around cabs.

The amount of energy required to operate an elevator depends on several factors, including: the height of the building, the number of stops, and passenger capacity. It is more efficient to select slower speeds while keeping the maximum waiting time to no more than 2 minutes. The assistance of the elevator manufacturer should be the first step in improving their efficiency.

LAUNDRIES

Laundries are a large energy user in hospitals and public care facilities. More efficient use can be considered without causing disruption. Peak power and water flow periods should be avoided. Water temperature should be regulated to meet health standards without going beyond those requirements. The heat recovery possibility should be carefully investigated and studied.

KITCHENS AND CAFETERIAS

Another large energy user is the kitchen/cafeteria operation. Staff in these areas should be aware of the energy savings they can generate. A memo with energy conservation opportunities in this area should be sent to them with the assistance of the kitchen supervisors enlisted. Generally, a heat pump water heater ECO is feasible if a kitchen is needed to prepare food twice a day.

Freezer and walk-in coolers can provide a source of heat for preheating water through the use of a special water heater which passes hot refrigerant through a coil next to the separate water storage tank. This will slightly increase efficiency of the refrigeration equipment.

EQUIPMENT AND MACHINES

Most buildings contain electrically driven machines which are left switched on and running. Many such machines are used only for a short periods of time. Make an inventory of all the office and vending machines to determine their periods of use. Request personnel to turn off office equipment when not in use. Time clocks may be installed for equipment only needed to operate short times. Exercise care to prevent damage to products stored in these machines. Drinking fountains shall not be shutdown.

Contact Energy Management Program for energy efficient office equipment information.

SUMMARY

If one adds the wattage of smaller incidental equipment in the building such as coffee pots, typewriters, printers, small copiers, radios. etc, the total usage may be surprising. For example, a large coffee pot may require up to 5,000 watts. Establish a building-wide awareness of energy consumption to minimize unnecessary use of all equipment. In particular, check that all equipment of this type is off overnight and during lunch periods.

During this equipment survey, remember that the State Fire Marshall and the Department of Personnel **require** that portable electric heaters be removed from state buildings.

REFERENCES

The following documents were used as reference for updating this handbook and are an excellent source of information on energy management. Also provided is a list of recommended reading materials, computer software and other useful information..

(1) American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1992. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc./ Illuminating Engineering Society (ASHRAE/IES) Standard 90.1-1989-Users Manual.

(2) American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1993. ASHRAE Handbook. 1993 Fundamentals..

(3) Canfield, K., 1987. Users Guild for Single Building Controllers. Department of the Navy.

(4) Enviro-Management & Research, Inc. Water Management - A Comprehensive Approach For Facility Managers.

(5) Environmental Protection Agency. April 1994. Green Lights Program - Lighting Upgrade Manual.

(6) Facilities Engineering Support Office. December 1987. Activity-Level Energy Systems Planning Procedure Computer Program Users Guide. Department of the Navy.

(7) Lindsey, Jack, FIES. 1990. Applied Illumination Engineering. The Fairmont Press, Inc.

(8) Nadel, Steven, et. al. , 1990, Energy Efficient Motors Systems: A Handbook on Technology, Program and Policy Opportunities, American Council for an Energy Efficient Economy.

(9) Pacific Northwest Laboratory. April 1990. Architect's and Engineer's Guide to Energy Conservation in Existing Buildings. Volume 2 - Energy Conservation Opportunities.

(10) Thumann, Albert, P.E., C.E.M. 1991. Plant Engineers and Managers Guide to Energy Conservation. The Fairmont Press, Inc.

(11) Turner, Wayne C., 1993. Energy Management Handbook. The Fairmont Press, Inc.

(12) Code of Federal Regulation Parts 435, 450 January 1, 1995

(13) ASHRAE 62-89, Ventilation for Acceptable Indoor Air Quality

(14) NISTIR 4481, The NIST "Building Life-Cycle Cost" (BLCC) Program

(15) DOE/EIA-0318 (89) Commercial Buildings Energy Consumption and Expenditures 1989

RECOMMENDED READING MATERIALS AND COMPUTER PROGRAMS

A partial list of publications and computer programs available (a catalog of all their publications is available from the organizations):

American Council for an Energy-Efficient Economy

ACEEE Publications
2140 Shattuck Avenue, Suite 202
Berkeley, CA 94704

Phone: (510) 549-9914

FAX: (510) 549-9984

Publications:

Energy-Efficient Motor Systems

Guide to Energy-Efficient Office Equipment

ACEEE Summer Study on Energy Efficiency in Buildings

What Works: Documenting the Results of Energy Conservation in Buildings

Office Equipment Energy Efficiency: Taking the Next Few Bytes

Energy-Efficient Lighting in Commercial Buildings

Controls to Reduce Electrical Peak Demands in Commercial Buildings

Association of Energy Engineers

AEE Energy Books
PO Box 1026
Lilburn, GA 30226

Phone: (404) 925-9558

FAX: (404) 381-9865

Publications:

Guide to Energy Management

Simple Solutions to Energy Calculations

HVAC Retrofits: Energy Savings Made Easy

Energy Conservation Guidebook

The Lighting Management Handbook

Lighting Efficiency Applications

Managing Indoor Air Quality

Optimizing HVAC Systems

Variable Air Volume Manual

U.S. Department of Commerce

National Institute of Standards and Technology (NIST)
Gaithersburg, MD 20899-0001

Phone: (301) 975-2000

Publications:

NBS Handbook 135, Life-Cycle Costing Manual for Federal Energy Management

Energy Prices and Discount Factors for Life-Cycle Cost Analysis

Building Life-Cycle Cost Computer Program (*See FEMP HELP DESK*)

U.S. Department of Energy

Federal Energy Management Programs
Washington, DC 20585

FEMP HELP DESK

Phone: 1- 800 566-2877

FEMP Office

Phone: (202) 586-5772

FAX: (202) 586-3000

Computer Programs (available by calling the FEMP HELP DESK):

A Simplified Energy Analysis Method (ASEAM)

Building Life-Cycle Cost (BLCC)

Publications:

Architect's and Engineer's Guide to Energy Conservation in Existing Buildings
(available from: National Technical Information Service Phone: (510) 934-4212)

(Vol. 1 - Energy Use Assessment and Simulation Methods)

(Vol. 2 - Energy Conservation Opportunities)

U.S. Department of Commerce

Springfield, VA 22161

Electric Power Research Institute (EPRI)

3412 Hillview Avenue
Palo Alto, CA 94304

Publications:

Commercial Cool Storage Primer

Commercial Cool Storage Design Guide

Water Treatment Technologies for Thermal Storage Systems

For a catalog of Research Reports contact:

EPRI Research Reports Center, or contact local TVA Power Distributor

PO Box 50490
Palo Alto, CA 94303

EPRI Computer Programs are available from:

Electric Power Software Center
1930 Hi Line Drive
Dallas TX 75207

Phone: (214) 655-8883

FAX: (214) 655-8772

MICRO-AXCESS - Building Energy Analysis Program

COMTECH - A Screening Tool for Commercial Building Technologies

HPSCAN - A tool to assist engineers in selecting the optimum heat exchanger/heat pump system for new or retrofit applications.

COOLAID - The Software Solution for Cool Storage Analysis

IESNA Illuminating Engineering Society of North America (IES)

120 Wall Street, 17 Floor
New York, NY 10005

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)

1791 Tullie Circle, NE
Atlanta, GA 30329

Phone: (404) 636-8400

FAX: (404) 655-8772

Publications:

ANSI/ASHRAE Standard 62 - 1989: Ventilation for Acceptable Indoor Air Quality

ASHRAE/IES Standard 90.1 - 1989: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings

ASHRAE/IES Standard 90.1 - 1989 User's Manual: A detailed instruction for the design of commercial and high-rise residential buildings so they comply with this Standard as well as the U.S.DOE Federal Standard 10 CFR 435.

ANSI/ASHRAE Standard 15 - 1994: Safety Code for Mechanical Refrigeration

ANSI/ASHRAE/IES Standard 100.2 - 1991: Energy Conservation in Existing Buildings - High-Rise Residential

ANSI/ASHRAE/IES Standard 100.3 - 1985: Energy Conservation in Existing Buildings - Commercial

ANSI/ASHRAE/IES Standard 100.4 - 1984: Energy Conservation in Existing Buildings - Industrial

ANSI/ASHRAE/IES Standard 100.5 - 1991: Energy Conservation in Existing Buildings - Institutional

ANSI/ASHRAE/IES Standard 100.6 - 1991: Energy Conservation in Existing Buildings - Public Assembly

U.S. Environmental Protection Agency

Air and Radiation (6202J)
Washington DC 20460

Green Lights Program

Technical Information:

Phone: (202) 862-1145

FAX: (202) 862-1144

FAX Back System: (202) 233-9659

Software Support:

Phone: (703) 934-3150

Customer Service:

Phone: (202) 775-6650
FAX: (202) 775-6680

Publications:

Lighting Upgrade Manual

Computer Software (contact Customer Service):

Green Lights Decision Support System (GL/DSS)

Internal Rate of Return Calculations (IRRkalc)

Green Lights Electronic Bulletin Board (GLBBS

MODEM Number: (202)775-6671

EPA co-sponsors the following:

National Lighting Product Information Program (NLPIP)

For more information send FAX to:
Lighting Research Center
Rensselaer Polytechnic Institute
(518) 276-2999

LIST OF ENERGY ORGANIZATIONS

American Council for an Energy-Efficient Economy (ACEEE)

1001 Connecticut Avenue, NW
Suite 801
Washington, DC 20036

2140 Shattuck Avenue, Suite 202
Berkeley, CA 94704

Phone: (510) 549-9914
Fax : (510) 549-9984

ACEEE is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection.

ACEEE publishes books, conference proceedings, and reports. The publications are not free.

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)

1791 Tullie Circle, NE
Atlanta, GA 30329

Phone: (404) 636-8400
FAX: (404) 655-8772
BBS (404) 235-0228

ASHRAE publishes Handbooks and Standards that are the basis for most energy conservation calculations and procedures. Publications are not free.

Association of Energy Engineers (AEE)

4025 Pleasantdale Road, Suite 420
Atlanta, GA 30340

phone:(404)447-5083

AEE conducts seminars and provides training for several energy management certification programs:

Certified Energy Manager (CEM)

Certified Lighting Efficiency Professional (CLEP)

Certified Indoor Air Quality Professional (CIAQP)

AEE publishes several periodicals and books on energy conservation. AEE membership, seminars, training, certifications, and publications are not free.

AEE members get discounts on seminars, books, and free subscriptions to:

Energy Engineering (Published bimonthly)

Strategic Planning for Energy and the Environment (published quarterly)

Energy User News (published monthly)

AEE Energy Seminars
PO Box 1026
Lilburn, GA 30226

Department of Energy (DOE)

Federal Energy Management Program, EE-44
Washington, DC 20585

Phone: (202) 586-5772

FAX: (202) 586-3000

FEMP HELP DESK: 1-800-566-2877

World Wide Web Home Page: http://www.doe.gov

FEMP provides free seminars and training for Life Cycle Costing (LCC), Building Energy Analysis (ASEAM), and Facility Energy Decision Screening System (FEDS). Computer software and manuals are included. FEMP also publishes a quarterly update bulletin that lists seminars and other useful information.

Environmental Protection Agency (EPA)

Green Lights Program
401 M Street, SW (6202J)
Washington DC 20460
ATTN: Surveyor Ally Program

Phone: (202) 293-4527

FAX: (202) 223-9534

World Wide Web Home Page: http://www.epa.gov

The Green Lights Program provides free seminars and training. If participants desire, they can take the test to become Surveyor Allies. The only cost is transportation, lodging and meals.

Green Lights/Energy Star Hotline: (202) 775-6650

Green Lights/Energy Star FAX: (202) 775-6680

Energy Star FAX Line System: (202) 233-9659

Electric Power Research Institute (EPRI)

3412 Hillview Avenue
Palo Alto, CA 94304

Phone: Report Orders: (415) 965-4081

Phone: Software Orders: (214) 655-8883

Phone: Technical Information: (415) 855-8958

World Wide Web Home Page: http://www.epri.com/database

EPRI provides technical reports and software programs for a wide variety of energy saving projects and are free to member utilities. They may or may not be free to a state government organization.

Illuminating Engineering Society of North America (IES)

120 Wall Street, 17th Floor
New York, NY 10005

Phone: (212) 248-5000

e-mail rharrolld@ix.netcom.com

IES publishes the Lighting Handbook - Reference and Application. The publication is not free.

National Renewable Energy Laboratory (NREL)

World Wide Web Home Page: http://www.nrel.gov

Office of the Federal Register

National Archives and Records Administration
Washington, DC 20408

Phone: (202) 512-1557

The Federal Register publishes the Code of Federal Regulations (CFR). Title 10, Parts 400 to 499, contain the Department of Energy requirements. Documents are not free. The document sales are handled by:

Superintendent of Documents
ATTN: New Orders
P. O. Box 371954
Pittsburgh, PA 15250-7954

Phone for Charge Orders: (202) 783-3238

APPENDIX-A (Click on link)

ENERGY AUDIT FORMS
(24 pages)

APPENDIX- B **(Click on Link)**

ECO CHECK LISTS

(37 pages)

APPENDIX-C
GLOSSARY OF COMMON ENERGY TERMS

ABSORPTION CHILLER:	A refrigeration machine using heat as the power input to generate chilled water
ADJUSTABLE SPEED DRIVE:	A means of changing the speed of a motor in a step-less manner. In the case of an AC motor this is accomplished by varying the frequency
AERATOR:	a device installed in a faucet or showerhead that adds air to the water flow, thereby maintaining an effective water spray while reducing overall water consumption
AIR CHANGES:	Replacement of the total volume of air in a room over a period of time. (e.g. 6 air changes per hour)
AMBIENT TEMPERATURE:	The temperature of the air surrounding an object
BALLAST:	A device used to supply the proper voltage and limit the current to operate one or more fluorescent or high intensity discharge lamps
BASE:	A selected period of time with consumption levels or dollar amounts, to which all future usage or costs are compared.
BLACKWATER:	water discharged from toilets, urinals, and kitchen sinks
BLCC:	Building Life Cycle Costing.
BLOW DOWN:	the discharge of water from a boiler or a cooling tower sump that contains a high proportion of total dissolved solids
BRITISH THERMAL UNIT (BTU):	The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2 Degrees Fahrenheit
BUILDING COMMISSIONING (CX):	A systematic process of assuring that a building facility performs in accordance with design intent and the owner's operational needs. Verification and documentation that all building facility systems perform interactively in an efficient manner and that operations and maintenance personnel are well trained
BUILDING ENVELOPE	The exterior surfaces of a building that are exposed to the weather, i.e.: walls, roof, windows, doors, etc.
CELSIUS (CENTIGRADE):	The temperature at which the freezing point of water is 0

degrees and the boiling point is 100 degrees at sea level.

CENTRIFUGAL FAN: A device for propelling air by centrifugal action.

CFM: Cubic feet per minute Usually refers to the volume of air being moved through an air duct.

CHILLER: A refrigeration machine using mechanical energy input to drive a centrifugal compressor to generate chilled water.

COEFFICIENT OF PERFORMANCE: Ratio of tons of refrigeration produced to energy required to operate equipment.

COEFFICIENT OF UTILIZATION: Ration of lumens on the work surface to total lumens emitted by the lamps.

COLD DECK: A cold air camber forming a part of an air conditioning system.

COMBINED WASTEWATER: A facility's total wastewater, both graywater and blackwater.

COLOR RENDERING INDEX (CRI): The color appearance of an object under a light source as compared to a reference source.

CONDENSATE: Water obtained by changing the state of water vapor (i.e. steam or moisture in air) from a gas to a liquid usually by cooling

CONDENSER: A heat exchanger which removes heat from vapor , changing it to its liquid state. In refrigeration systems this is the component which rejects heat.

CONDUCTION: Method of heat transfer in which heat moves through a solid.

CONVECTION: Method of heat transfer in which heat moves by motion of a fluid or gas, usually air.

COOLING TOWER: A device that cool water directly by evaporation.

CENTER FOR RESEARCH, SERVICE AND INQUIRY, INCORPORATED (CRSI, INC.): A nonprofit corporation in Tennessee that specializes in energy efficiency program design and delivery. Committed to systems reliability, Indoor Environmental Quality and persistence of savings. (John E. Sicard, AIA and E. Avery Phillips, PE
Phone No. 423/6370743.)

DAMPER: A device used to limit the volume of air passing through an air outlet, inlet or duct.

DEGREE DAYS: The degree day for any given day is the difference between 65 degrees and the average daily temperature. For example, if the average temperature is 50 degrees, the degree days is 65 - 50 = 15 degree days. When accumulated for a season, degree days measure the severity of the entire season.

DEMAND LOAD: The maximum continuos requirement for electricity measured during a specified amount of time, usually 15 minutes.

DEMAND FACTOR: The ratio of the maximum demand of a system to the total connected load on the system.

DOUBLE BUNDLE CHILLER: A condenser usually in a refrigeration machine) that contains two separate tube bundles allowing the option of rejecting heat to the cooling tower or to another building system requiring heat input.

DRY BULB TEMPERATURE: The measure of the sensible temperature of air.

ECONOMIZER CYCLE: A method of operating a ventilation system to reduce refrigeration load. Whenever the outside air conditions are more favorable (lower heat content) than return air conditions, outdoor air quantity is increased.

EFFICACY: Ratio of usable light to energy input for a lighting fixture or system (lumens per watt)

ENERGY MANAGEMENT SYSTEM: A microprocessor based system for controlling equipment and monitoring energy and other operating parameters in a building.

ENERGY REQUIREMENT: The total yearly energy used by a building to maintain the selected inside design conditions under the dynamic impact of a typical year's climate. It includes raw fossil fuel consumed in the building and all electricity used for lighting and power. Efficiencies of utilization are applied and all energy is expressed in the common unit of BTU.

ENERGY UTILIZATION INDEX: A reference which expresses the total energy (fossil fuel and electricity) used by a building in a given period (month, year) in terms of BTU's/gross conditioned square feet.

ENTHALPY: The total heat content of air expressed in units of BTU/pound. It is the sum of the sensible and latent heat.

EVAPORATOR: A heat exchanger in which a liquid evaporates while absorbing heat.

EVAPORATION: The act of water or other liquids dissipating or becoming vapor or steam.

FAUCET AERATOR: Either a device inserted into a faucet head or a type of faucet head that reduces waterflow by adding air to the water stream through a series of screens and/or small holes through a disk. An aerator produces a low-flow non-splashing stream of water

FLOW RESTRICTORS: washer like disks that fit inside faucet or shower heads to restrict waterflow.

FLUSHOMETER VALVE TOILET: Also known as a pressure assisted or pressurized tank toilet, a toilet with the flush valve attached to a pressurized water supply tank. When activated, the flush valve supplies the water to the toilet at the higher flow rate necessary to flush all of the waste through the toilet trap and into the sewer.

FOOT CANDLE: Illumination at a distance of one foot from a standard candle

GRAVITY FLUSH TOILET: A toilet designed with a rubber stopper that releases stored water from the toilet's tank. Gravity flow water then fills the bowl and carries the waste out of the bowl, through the trap and into the sewer.

GRAYWATER: Used water discharged by sinks, showers, bathtubs, clothes washing machines, and the like.

GROSS SQUARE FEET: The total number of square feet contained in a building envelope using the floors as area to be measured.

HEAT GAIN: As applied to HVAC calculations it is that amount of heat gained by a space from all sources including people, lights, machines, sunshine, etc. The total heat gain represents the amount of heat that must be removed from a space to maintain indoor comfort conditions. This is usually expressed in BTU's per hour.

HEAT LOSS: The heat loss from a building when the outdoor temperature is lower than the desired indoor temperature It represents the amount of heat that must be provided to a space to maintain indoor comfort conditions. This is usually expressed in BTU/hour.

HEAT PUMP: A refrigeration machine possessing the capability of reversing the flow so that its output can be either heating or cooling. When used for heating it extracts heat from a low temperature source.

HEAT TRANSMISSION COEFFICIENT: Any one of a number of coefficients used in the calculation of heat transmission by conduction, convection, and radiation, through various materials and structures.

HORSEPOWER: British unit of power, 1 Hp. = 746 watts or 42,408 BTUs per minute.

HOT DECK: A hot air chamber forming part of a multizone or dual duct air handling unit

HUMIDITY, RELATIVE: A measurement indicating the moisture content of the air.

IAQ: Indoor Air Quality

IEQ: Indoor Environmental Quality

INFILTRATION: The process by which outdoor air leaks into a building by natural forces through cracks around doors and windows, etc.

LATENT HEAT: The quantity of heat required to effect a change in state of a substance.

LIFE CYCLE COST: The cost of the equipment over its entire life including operating costs, maintenance costs and initial cost.

LOW FLOW TOILET: A toilet that uses 3.5 gallons of water per flush**.**

LOAD PROFILE: Time distribution of building heating, cooling, and electrical load.

LUMEN: Unit of measurement of the rate of light flow.

LUMINAIRE: Light fixture designed to produce a specific effect.

MAKEUP: Water supplied to a system to replace that lost by blowdown, leakage, evaporation, etc. Air supplied to a system to provide for combustion, and/or ventilation.

MODULAR: System arrangement whereby the demand for energy (heating, cooling) is met by a series of units sized to meet a portion of the load.

ORIFICE PLATE: Device inserted in a pipe or duct which causes a pressure drop across it. Depending on orifice size it can be used to restrict flow or form part of a measuring device.

ORSAT APPARATUS: A device for measuring the combustion components of boiler or furnace flue gasses.

PIGGYBACK OPERATION: Arrangement of chilled water generation equipment whereby exhaust steam from a steam turbine driven centrifugal chiller is used as the heat source of an absorption chiller

PLENUM: A large duct used as a distributor of air from a furnace

POTABLE WATER: clean, drinkable water; also known as “white” water.

POWER FACTOR: Relationship between KVA and KW. The power factor is one when the KVA equals the KW.

PRESSURIZED TANK TOILET: A toilet that uses a facility’s waterline pressure by pressurizing water held in a vessel within the tank, compressing a pocket of trapped air. The water releases at a force 500 times greater than a conventional gravity toilet.

PRESSURE REDUCING VALVE: A valve designed to reduce a facility’s water consumption by lowering water pressure.

RADIATION: The transfer of heat from one body to another by heat waves without heating the air between them.

R VALUE: The resistance to heat flow of insulation.

SEASONAL EFFICIENCY: Ratio of useful output to energy input for a piece of equipment over an entire heating or cooling season. It can be derived by integrating part load efficiencies against time.

SENSIBLE HEAT: Heat that results in a temperature change, but no change in state.

SIPHONIC JET URINAL: A urinal that automatically flushes when water, which flows continuously to its tank, reaches a specified preset level.

SOURCE METER: A water meter that records the total waterflow into a facility.

SUB METER: A meter that records energy or water usage by a specific process, a specific part of a building, or a building within a larger facility.

THERM: A unit of gas fuel containing 100,000 BTUs

TON (OF REFRIGERATION): A means of expressing cooling capacity: 1 Ton = 12,000 BTU/hour cooling (removal of heat).

U VALUE: A coefficient expressing the thermal conductance of a composite structure in BTUs per (square foot) (hour) (degree Fahrenheit difference).

ULTRA LOW FLOW TOILET: A toilet that uses 1.6 gallons or less of water per flush.

VARIABLE SPEED DRIVE: See “Adjustable speed Drive”.

VARIABLE FREQUENCY DRIVE: See “Adjustable speed Drive”.

VEILING REFLECTION: Reflection of light from a task or work surface into the viewer’s eyes.

VAPOR BARRIER: A moisture impervious layer designed to prevent moisture migration.

WET BULB TEMPERATURE: The lowest temperature attainable by evaporating water in the air without the addition or subtraction of energy.

XERISCAPING: the selection, placement, and care of water-conserving and low-water-demand ground covers, plants, shrubs, and trees in landscaping

APPENDIX-D

ABBREVIATIONS

ADA	Americans with Disabilities Act
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BLCC	Building Life Cycle Cost
BTU	British Thermal Unit
BTUH	BTU per hour
CFC	Chlorofluorocarbons
CCF	Centicubic feet (100 cubic feet)
CFM	Cubic feet per minute
CRI	Color rendering index
COP	Coefficient of performance
CU	Coefficient of utilization
DB.	Dry bulb temperature
DOE	Department of Energy
ECO	Energy conservation opportunity
EMCS	Energy management and control system
EUI	Energy Utilization Index
IAQ	Indoor air quality
IES	Illumination Engineering Society
GPH	Gallons per hour
GPM	Gallons per minute
HID	High intensity discharge (lamps)
HP	Horsepower
HPS	High pressure sodium (lamps)
HVAC	Heating, ventilating, and air conditioning
KBTU	Thousands of BTUs
KVA	Kilovoltampere
KWH	Kilowatthour
MBTU	Millions of BTUs
MH	Metal halide (lamps)
O.A.	Outside air
P. F.	Power factor

psia	Pounds per square foot absolute
psig	Pounds per square foot gauge
sq. ft. / s.f.	Square feet
TD	Temperature difference
TE	Total Energy (system)
WB.	Wet Bulb temperature

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